

**Before the  
FEDERAL COMMUNICATIONS COMMISSION  
Washington, D.C. 20554**

In the Matter of	)	
	)	
Expanding Access to Mobile Wireless	)	WT Docket No. 13-301
Services Onboard Aircraft	)	
	)	

**REPLY COMMENTS OF  
AEROMOBILE COMMUNICATIONS LIMITED**

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## SUMMARY

AeroMobile Communications Limited (“AeroMobile”) applauds the Federal Communications Commission’s (“Commission”) commitment to bringing the significant public benefits of in-flight mobile connectivity (“IMC”) to the United States. By initiating this rulemaking, the Commission has taken a critical step towards more fully realizing benefits of mobile broadband applications while simultaneously improving the operating environment for mobile broadband providers. IMC systems allow consumers to remain connected onboard aircraft, just as they would on the ground, and have the important additional benefit of controlling mobile devices left in transmit-mode onboard aircraft in flight. The Commission should bring these benefits to consumers and their wireless carriers by permitting IMC operations onboard international flights of U.S. and foreign airlines, and encouraging industry to expeditiously develop any additional technical or regulatory provisions that may be appropriate to support IMC operations onboard U.S. domestic flights.

The Commission can act quickly to bring the benefits of IMC to the United States by recognizing the authority issued to foreign airlines by their home licensing administrations, subject to compliance with existing IMC standards. This approach is consistent with principles of international license recognition embodied in the Chicago Convention and ITU Radio Regulations and with the practice of many countries around the world. To the extent a more formal rules-based approach may be considered, and to enable IMC on international flights of U.S. airlines, AeroMobile encourages the Commission to adopt technical rules under its Part 15 equipment authorization regime that incorporate existing international standards.

In either case, AeroMobile submits that the Commission need not authorize IMC operations as a new “airborne mobile service.” Rather, IMC is simply an extension of a

passenger's existing mobile service – using the passenger's own mobile device and subject to the existing relationship with the passenger's chosen carrier – that is accessed onboard aircraft in flight through airborne access system (“AAS”) technology. The Commission thus need only consider the operation of AAS equipment onboard the aircraft, which can be accomplished by a statement of policy recognizing foreign aircraft licensing or by a Part 15 provision that incorporates existing IMC standards for U.S. aircraft serving international routes.

AeroMobile believes the Commission should enable IMC initially onboard international flights for several reasons. First, although the record of this proceeding establishes the non-interfering nature of IMC operations, permitting IMC on international flights will limit the number of equipped aircraft and allow potentially affected spectrum users to monitor any impact of these operations. Second, existing IMC implementations are based on an international roaming model and passengers who are travelling onboard international flights, whether operated by U.S. or foreign airlines, are more likely to have mobile devices and roaming plans that will enable access to IMC applications.\* Third, practical implementation issues have been considered fully by foreign airlines that offer IMC so any social or operational concerns are certainly not an impediment to Commission action, and U.S. airlines can obtain experience with IMC offerings for international routes on which they must compete with IMC-equipped foreign airlines. Finally, any lessons learned from international IMC operations can be factored into the development of an IMC regulatory regime for U.S. domestic flights.

Although the Commission should expeditiously permit IMC operations onboard international flights pursuant to existing technical standards, additional consideration may be

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\* Indeed, today a full twenty percent of IMC users on flights to and from the United States are U.S. wireless carrier subscribers.

necessary to develop rules for IMC implementation on domestic flights based on U.S. commercial mobile spectrum bands. Therefore, AeroMobile urges the Commission allow interested parties to undertake additional consultations and file a progress report no later than December 31, 2014 providing recommendations to enable IMC operations on U.S. domestic flights.

AeroMobile stands ready to work with the Commission and interested parties to facilitate the implementation of IMC in the United States. By enabling IMC operations on international flights in the near term and addressing additional domestic technical and regulatory issues in a further phase of this proceeding, the Commission will bring the benefits of current IMC offerings to the U.S. traveling public at the earliest practicable time while affording interested parties the opportunity to develop a domestic IMC offering that can maximize the benefits of in-flight mobile broadband in the United States.

## Table of Contents

I. Introduction.....	1
II. Discussion.....	3
A. The Commission Should Expand the Benefits of IMC to the U.S. Public .....	5
B. Operation of AAS Equipment on International Flights Would Raise No Technical Issues or Interference Concerns .....	8
1. AASs Can Operate in the United States on a Non-Interference Basis Pursuant to Existing International Standards .....	9
a) The Extensive Body of Technical Work, As Supplemented in the Proceeding, Confirms Non-Interfering Operations.....	9
b) The Technical Questions Raised by CTIA Regarding International IMC Operations Have Been Addressed Fully .....	10
2. AAAs Can Operate in the 1800 MHz Band Without Adversely Affecting U.S. Government Operations .....	16
a) IMC Picocell and Mobile Device Operations Would Not Cause Harmful Interference to Other Users of the 1800 MHz Band .....	17
b) The Potential Interference Impact of IMC Operations Would Be De Minimis and Similar to that of Part 15 Devices .....	19
c) At a Minimum, the Commission Should Permit Mobile Device Uplinks in the 1755-1780 MHz Band.....	21
C. The Commission Should Expeditiously Enable Operation of AASs on International Flights in the United States .....	22
1. The Commission Can Permit AAS Operation in U.S. Airspace by Recognizing Foreign AAS Authorizations .....	23
2. Part 15 Provides a Viable Basis for IMC in the United States .....	25
3. In Any Event, the Commission Need Not Require IMC Providers to Comply with Part 20 CMRS Rules .....	26
4. IMC Providers Have Accepted CALEA Obligations and Can Address Security Issues through Individual Negotiations .....	29
III. Conclusion .....	30

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AeroMobile Communications Limited (“AeroMobile”) respectfully submits these reply comments in the above-captioned proceeding in which the Commission seeks to facilitate the introduction of in-flight mobile connectivity (“IMC”) in the United States.<sup>1</sup> Specifically, the Commission proposes to adopt new rules that permit operation of airborne access systems (“AASs”) and associated mobile devices onboard aircraft in flight in a manner compatible with other U.S. systems and services. AeroMobile strongly supports the Commission’s IMC initiative and believes existing AASs should be permitted to operate on international flights to and from the United States while industry works with the Commission to develop rules governing IMC operations on U.S. domestic flights.

**I. Introduction**

AeroMobile, a U.K.-based affiliate of Panasonic Avionics Corporation, has developed AAS equipment that enables aircraft passengers and crew to use mobile handsets for voice, text and data applications while in flight, just as they would on the ground. AeroMobile has installed its equipment on 220 aircraft (expected to increase to 300 within the next 12 months), of which

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<sup>1</sup> *Expanding Access to Mobile Wireless Services Onboard Aircraft*, WT Docket No. 13-301, Notice of Proposed Rulemaking, FCC 13-157, 28 FCC Rcd 17132 (2013) (hereinafter “NPRM”).

approximately twenty percent operate on routes to and from the United States. As the Commission is aware, however, AeroMobile currently suspends IMC operations while equipped aircraft are present in U.S. airspace, thereby depriving air travelers of the benefits of mobile broadband connectivity when the need to communicate with others is most important – just after take-off and just before landing in the United States.

AeroMobile strongly supports the Commission’s initiative to clear the way for IMC operations in the United States. As broadband-enabled mobile services have become widely available and an increasingly essential part of daily life, airline passengers today want and expect their mobile devices to operate, even while in flight. The connectivity they provide has gained heightened importance to the traveling public, who rely on mobile applications to meet their communications needs while on the road and, now, in the air. Although IMC is currently available only on foreign airlines, AeroMobile expects that U.S. airlines serving international routes will soon seek to offer this connectivity option – especially once AeroMobile’s next-generation AAS equipment is introduced later this year.

The record of this proceeding, as well as a substantial body of preexisting evidence and real-world experience, establishes that existing IMC systems may operate in U.S. airspace on an unprotected, non-interference basis pursuant to well-settled international standards. The low power levels of AAS and mobile device transmissions, fuselage attenuation and large separation distances confirm that IMC operations will have no detrimental effect on the operation of other systems and services in the United States. To the contrary, the use of AAS technology on aircraft will substantially improve the operating environment for mobile wireless carriers by controlling handsets left powered on and in transmit mode onboard aircraft.

The Commission should enable existing AAS equipment to operate on international flights present in U.S. airspace pursuant to existing standards. AeroMobile submits that the most expeditious and straightforward way for the Commission to do so would be to recognize IMC authorizations granted to foreign airlines by their home administrations, consistent with well-settled legal principles in international civil aviation. To the extent more formal, rule-based authority may be appropriate in the longer term, and to facilitate IMC onboard U.S. aircraft traveling on international routes, AeroMobile urges the Commission to incorporate existing IMC standards in Part 15 of its rules.

There is currently no AAS equipment designed to operate using the specific commercial mobile spectrum bands and air interfaces chosen by U.S. domestic wireless carriers. Although it is possible that next-generation AASs equipped with the 2100 MHz connectivity band could be used on domestic flights successfully, interested parties may seek to use other U.S. connectivity bands. Thus, additional regulatory work may be appropriate to develop rules for IMC operations on U.S. domestic flights. The Commission should afford interested parties time to consider such issues even while it permits IMC onboard aircraft traveling to and from the United States.

## **II. Discussion**

The Commission should expeditiously enable IMC operations in U.S. airspace on international flights of U.S. and foreign airlines. As the Commission acknowledges in the *NPRM*, IMC offerings are simply mobile broadband applications available onboard aircraft.<sup>2</sup> AASs and associated mobile devices operate pursuant to well-defined technical standards to extend the reach of licensed wireless carriers to their existing subscribers. Enabling AAS

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<sup>2</sup> *NPRM* at ¶ 32.

operations on international flights would promote the public interest by expanding mobile broadband coverage to consumers in the most efficient and non-interfering manner.<sup>3</sup>

Importantly, IMC is already available to U.S. consumers aboard AAS-equipped aircraft outside of U.S. airspace pursuant to authority issued by an airline's home licensing administration. Given this existing authority, there is no need for the Commission to re-license or impose service-related requirements while foreign-registered aircraft are temporarily present in U.S. airspace. IMC also can be expeditiously introduced on international flights of U.S. airlines by incorporating existing IMC standards in Part 15 of the Commission's rules. Although no U.S. airlines currently offer IMC, several have expressed interest in next-generation systems and the Commission should ensure that its regulations will support this connectivity amenity.

IMC systems have been certified as compliant with international standards by the U.S. Federal Aviation Administration ("FAA") or European Aviation Safety Agency ("EASA"), depending on the manufacturer of the aircraft. Thus, the Commission can be assured that international IMC operations are fully compliant with existing standards without the need for duplicative licensing or certification.

Of course, the Commission also should afford interested parties time to consider additional issues that may be pertinent to IMC operations onboard domestic flights. AeroMobile has been engaged in extensive consultations with CTIA and its members to identify and address potential issues related to U.S. domestic and international IMC operations. AeroMobile has also been engaged with U.S. government representatives to ensure that limited, low-power IMC operations within the aircraft cabin using 1800 MHz spectrum is well understood and will not cause interference to federal government operations in the band.

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<sup>3</sup> *NPRM* at ¶ 56.

Although progress has been made with respect to examining existing IMC standards and assessing the potential impact of IMC operations onboard international flights on U.S. systems and services, further work is needed to consider implementation of IMC offerings on U.S. domestic flights. Thus, the Commission should permit interested parties to continue their work and provide a progress report to the Commission no later than December 31, 2014 for further consideration in this proceeding.

**A. The Commission Should Expand the Benefits of IMC to the U.S. Public**

As the Commission notes in the *NPRM*, consumers increasingly demand broadband connectivity on aircraft, and airlines have deployed technology to meet this demand.<sup>4</sup> Despite the consumer demand for IMC and non-interfering nature of IMC operations, foreign airlines suspend the offering before entering U.S. airspace given the absence of an IMC regulatory regime or other guidance from the Commission. Accordingly, it is not surprising that the *NPRM* received support from a variety of stakeholders, including airlines and aircraft manufacturers, IMC equipment integrators and service providers, and technology and telecommunications industry associations.

Enabling IMC in the United States would serve the public interest by promoting competition, innovation, and investment in new mobile broadband and in-flight connectivity offerings. By authorizing IMC in the United States, the Commission also would take another important step to achieve its overarching policy goal to expand the availability of broadband nationwide. As the Commission stated in the National Broadband Plan, “[u]biquitous availability of broadband and universal connectivity enable people and entities in the United

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<sup>4</sup> See *NPRM* at ¶ 2.

States to communicate worldwide, which increases productivity and enables innovation.”<sup>5</sup>

Today, the airplane cabin is one of the least connected transit spaces in the nation. Trains, buses and even subways generally provide passengers with direct access to their chosen mobile service provider. But, speed, altitude, and coverage issues have prevented airplane passengers from easily accessing mobile broadband applications, at least in the past. IMC closes that gap, extending the well-recognized educational, economic, cultural, civic, and social benefits of mobile broadband to aircraft.

The intense interest in in-flight connectivity is confirmed by AT&T’s recent announcement that it will develop and implement an LTE-based in-flight connectivity solution.<sup>6</sup> However, AT&T’s preliminary air-ground announcement should not be confused with IMC offerings, which provide access to mobile broadband applications within the aircraft cabin using AAS technology. There is no basis to conclude that AT&T’s contemplated offering is anything other than a terrestrial off-board link, like that provided by Gogo in 800 MHz spectrum. If AT&T seeks authority for IMC as well, then the Commission should act quickly to ensure adequate competition from other IMC providers. And in no event should AT&T’s preliminary announcement be viewed as obviating the need to enable IMC in the United States. Rather, the Commission should still move expeditiously to expand the availability of in-flight mobile broadband and, because AT&T’s proposal is only a U.S. domestic solution, recognize that satellite-based IMC utilizing AAS technology such as that provided by AeroMobile is still

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<sup>5</sup> Federal Communications Commission, Omnibus Broadband Initiative, *Connecting America: The National Broadband Plan*, (2010), at 60.

<sup>6</sup> Press Release, Mobilizing the Sky: AT&T Building 4G LTE In-Flight Connectivity Service (Apr. 28, 2014), *available at* [http://about.att.com/story/mobilizing\\_the\\_sky\\_att\\_building\\_4g\\_lte\\_in\\_flight\\_connectivity\\_service.html](http://about.att.com/story/mobilizing_the_sky_att_building_4g_lte_in_flight_connectivity_service.html).

required for U.S. airlines seeking to offer the connectivity amenity to passengers on long-haul international flights.

Enabling IMC in the United States will have the important additional benefit of improving the operating environment for U.S. wireless carriers by preventing airborne mobile devices from communicating with the terrestrial network. A large number of mobile devices are inadvertently or deliberately left powered on and in transmit mode, which means they are entirely uncontrolled and will likely transmit at maximum power in an effort to connect to terrestrial base stations. However, the masking and control features of AASs— which are essential aspects of IMC operations -- effectively prevent passenger devices from transmitting at high power and potentially connecting to tower sites below.<sup>7</sup> Enabling IMC in United States, even initially on international flights as proposed by AeroMobile, would improve the operating environment for wireless carriers and would provide an opportunity for the Commission and industry participants to assess this positive impact of IMC operations in U.S. airspace.

Finally, in considering rules to enable IMC in the United States, the Commission need not consider issues regarding the potential impact of specific IMC applications, such as voice services, on the air travel experience.<sup>8</sup> Passenger safety, consumer protection and airline operational concerns with respect to IMC voice applications are being addressed in a companion proceeding before the Department of Transportation (“DoT”).<sup>9</sup> AeroMobile agrees with other

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<sup>7</sup> Association of Flight Attendants-CWA, AFL-CIO Comments at 3 (“Given that cell phones are often routinely left powered on and transmitting in cellular bands during flight, the NCU would ensure that potential interference with onboard communications and navigation systems is managed safely and that the risk of airborne cell phones interfering with terrestrial networks is mitigated.” (footnote omitted)).

<sup>8</sup> *NPRM* at ¶ 73.

<sup>9</sup> *Use of Mobile Wireless Devices for Voice Calls on Aircraft*, Department of Transportation, Advance Notice of Proposed Rulemaking, 79 Fed. Reg. 10049 (Feb. 24, 2014) (hereinafter

commenting parties that the Commission should limit its inquiry to technical issues and regulatory policy relating to the functionality of AAS equipment, such as the potential to interfere with existing spectrum usage, and leave airlines to decide (within any limitations imposed by DoT) which types of IMC applications to enable onboard their aircraft.<sup>10</sup>

**B. Operation of AAS Equipment on International Flights Would Raise No Technical Issues or Interference Concerns**

Current IMC implementations are based on an international roaming model, and the Commission should authorize their operation in the United States to bring the benefits of existing IMC offerings to U.S. consumers. By enabling current IMC systems to operate on international flights in U.S. airspace, the Commission would expand mobile broadband to consumers in an efficient, non-interfering manner<sup>11</sup> and consumers would benefit from uninterrupted access to IMC applications. At the same time, such an authorization would give the Commission and

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“DoT ANPRM”). *See* Transport Workers Union of America, AFL-CIO (TWU) Comments, Association of Professional Flight Attendants Comments, Association of Flight Attendants-CWA, AFL-CIO Comments.

<sup>10</sup> If such operational regulation is necessary, then the DoT is the appropriate authority to consider and adopt such provisions. DoT ANPRM at 10049 (“In general, . . . the FCC has authority over various technical issues, the Federal Aviation Administration (FAA) which is a component of DOT has authority over safety issues, and DOT’s Office of the Secretary (OST) has authority over aviation consumer protection issues”); Panasonic Avionics Comments at 22, Alliance for Passenger Connectivity Comments at 13, Row44 Inc. Comments at 5, Competitive Enterprise Institute Comments at 8-9. AeroMobile agrees with Chairman Wheeler, who stated that the Commission’s “mandate from Congress is to oversee how networks function” and a decision related to permitting or prohibiting specific IMC applications such as voice calls would not be within the FCC’s technical expertise as an agency. Testimony of Thomas Wheeler, Chairman, Fed. Commc’ns Comm’n Before the Subcomm. on Commc’ns and Tech. Comm. On Energy and Commerce U.S. House of Representatives “Oversight of the Fed. Commc’ns. Comm’n,” at 8 (Dec. 12, 2013). Therefore, the Commission need not address such issues in the context of this proceeding.

<sup>11</sup> *NPRM* at ¶ 56.

interested parties additional real-world information to develop a regulatory framework for IMC on domestic flights.

**1. AASs Can Operate in the United States on a Non-Interference Basis Pursuant to Existing International Standards**

Extensive technical analyses, as clarified and supplemented in this proceeding, establish that existing AASs may operate in the United States pursuant to existing technical standards without causing harmful interference with terrestrial systems and services. In addition, these systems may operate in the 1800 MHz band without causing interference to U.S. government systems.

**a) The Extensive Body of Technical Work, As Supplemented in the Proceeding, Confirms Non-Interfering Operations**

The technical parameters for current operations of AASs are based on international standards set forth by the Electronic Communications Committee (“ECC”) of the European Union (“EU”) Conference of Postal and Telecommunications Administrations (“CEPT”).<sup>12</sup> These standards also have been endorsed by the Asia Pacific Telecommunity (“APT”) and adopted by countries around the world to facilitate the availability of IMC virtually everywhere in the world outside of U.S. airspace.

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<sup>12</sup> Consistent with international standards, the first generation picocell on AeroMobile’s AAS communicates with mobile devices in the 1800 MHz band using Global System for Mobile (“GSM”) technology. AeroMobile’s next generation picocell is designed to communicate in the 1800 MHz and 2100 MHz band using GSM, Universal Mobile Telecommunications System (“UMTS”) and Long-Term Evolution (“LTE”) technologies in accordance with the recently updated IMC standards. Report from CEPT to the European Commission in response to the Second Mandate to CEPT on mobile communication services on board aircraft (MCA), CEPT Report 48 (Mar. 8, 2013), *available at*: <http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP048.PDF> (CEPT MCA Report 48).

AeroMobile agrees with the Commission and other commenting parties that technical studies completed by the EU's CEPT would provide a solid foundation for the FCC's authorization of IMC in the United States.<sup>13</sup> AeroMobile attached a Technical Appendix to its initial comments which provided information regarding the technical characteristics of AeroMobile's AAS operations, reflecting the existing international standards, and interference assessments that demonstrate that existing AASs can operate successfully in U.S. airspace without causing interference to other systems and services.<sup>14</sup> Similarly, OnAir demonstrated in its comments that the results of the CEPT technical studies "can be readily extrapolated" to the U.S. commercial mobile spectrum bands and mobile air interfaces.<sup>15</sup>

In developing the original and updated IMC standards, extensive interference analyses were conducted with significant input from wireless carriers, equipment manufacturers, the aviation community and the government sectors. The impact of AAS and mobile device transmissions were evaluated for a broad range of frequencies, air interfaces and potentially affected services. Permissible operating parameters were approved only after conclusive demonstration that AAS operations would have no impact on other systems and services.

**b) The Technical Questions Raised by CTIA Regarding International IMC Operations Have Been Addressed Fully**

AeroMobile has worked with the U.S. government and industry participants over the past several years to enhance the understanding of IMC services in the United States. More recently, AeroMobile has engaged with CTIA – The Wireless Association ("CTIA") to host several wireless industry educational sessions and, in response the Commission's extension of the reply

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<sup>13</sup> See *NPRM* at ¶ 33, Boeing Comments at 5, OnAir Comments at 11-15.

<sup>14</sup> See Technical Appendix to AeroMobile Comments.

<sup>15</sup> OnAir Comments at 11-15.

comment deadline in this proceeding, to hold detailed technical and policy discussions with CTIA members. AeroMobile appreciates the constructive dialogue that has taken place to date with CTIA and its membership, and we look forward to continuing to work with the U.S. wireless industry to develop appropriate provisions governing U.S. domestic IMC operations.

AeroMobile differs with CTIA on certain positions relating to the scope and modeling assumptions associated with the development of existing international standards for IMC operations. Some of these issues were raised in CTIA's original comments in this proceeding.<sup>16</sup> Others were raised in the context of additional technical consultations with CTIA over the past three months. AeroMobile addresses below some of these issues raised in CTIA's comments and provides an additional Technical Appendix with these reply comments to supplement the record of this proceeding.<sup>17</sup>

*Spectrum and Air Interface Differences.* CTIA suggests, for example, that different or new commercial wireless bands and air interfaces used in the United States make reliance on international studies and standards impossible. In response, AeroMobile notes that ECC Report 187, as well as underlying studies and related standards, address a wide range of frequencies and technologies, and any differences between the European and U.S. commercial mobile systems would not alter the fundamental conclusion of the studies: that AAS systems are compatible with terrestrial mobile wireless systems. Moreover, the radio compatibility modeling techniques and system parameters drawn from international technical standards can be applied to U.S. commercial mobile bands without changing the underlying analytical approaches. The Technical Appendix attached to AeroMobile's original comments explained these issues and analyzed AAS

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<sup>16</sup> CTIA Comments at 4-7.

<sup>17</sup> See *infra* Technical Appendix.

operations in U.S. mobile bands, and the supplemental Technical Appendix attached hereto provides additional information regarding the international standards and analytical methodologies demonstrating they can be used to assess the potential impact of AAS operations in the United States.

In particular, the existing technical studies are extremely conservative in their approach, including the values for transmission level from IMC equipped aircraft assume worst case position relative to a victim receiver (angle to the ground) and do not account for aircraft motion. An equipped aircraft is actually at the worst case position only momentarily and otherwise is flying rapidly towards or away from that position and thus more typically in the lower sidelobes of the victim antenna.<sup>18</sup> In addition, recognizing that the radio spectrum allocations for mobile services is subject to change over time in a given country and/or region, AeroMobile has developed a next-generation programmable NCU that can dynamically adjust for control bands from 400 MHz to 4 GHz. Thus, any differences in U.S. mobile spectrum bands have been accounted for directly in the analysis, actual IMC equipment capabilities (e.g., frequency agile NCUs) or are immaterial to concerns regarding the interference potential from IMC operations.

*Fast Adaptive Power Control (CDMA, UMTS and LTE).* CTIA further suggests that the existing studies do not account for fast adaptive power control across various air interfaces. However, the studies were performed using minimum coupling loss (MCL) and Monte-Carlo analysis to simulate the interference environment and SEAMCAT (the ECC's modeling software used for all analysis of interference to IMT systems), incorporates a TDMA, CDMA, and OFDMA modules to account for the different technologies which have been deployed.

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<sup>18</sup> Thus, among other things, the fleeting nature of potential interference resulting from the speed of the aircraft support the extremely conservative nature of existing analyses and reliance on these analyses in considering the potential impact of IMC in the United States.

Each module accounts, in significant detail, for the technical and operational differences of the different technologies. For the CDMA simulations conducted by the ECC, the device power control was accounted for in the model. The following screenshot illustrates the ac-UE power control range may be modeled using SEAMCAT.

**Figure 1. SEAMCAT CDMA Power Control**

The screenshot shows the 'Victim Link' dialog box in SEAMCAT. The 'General' tab is active, and the 'CDMA' link component is selected. The 'Uplink' radio button is chosen for the 'CDMA Link component'. The 'Uplink Model' section, highlighted with a red box, includes the following parameters:

Parameter	Value	Unit
Target Network Noise Rise	6.0	dB
Mobile Station Maximum Transit Power	21.0	dBm
Mobile Station Power Control Range	71.0	dB
PC Convergence precision (linear)	0.1	dB

The 'Downlink Model' section includes the following parameters:

Parameter	Value	Unit
Base Station Pilot Channel Fraction	0.15	
Base Station Overhead Channel Fraction	0.005	
Base Station Maximum Broadcast Power	21.0	dBm
Base Station Maximum Traffic Channel Power	0.15	
Success Threshold	0.5	dB

Other parameters in the 'General' tab include Receiver Noise Figure (5.0 dB), Handover Margin (3.0 dB), Call drop threshold (3.0 dB), Voice bit rate (12.2 kbs), Reference bandwidth (3.84 MHz), Voice activity factor (0.5), and Minimum Coupling Loss (70.0 dB). The 'Link Level Data' dropdown is set to 'W-CDMA/UMTS : QUALCOMM Europe : 835.0 MHz : uplink : 1% FER'.

More importantly, the onboard AAS has the ability to control the maximum mobile device transmit power. AeroMobile's onboard system can control the transmit power from the 3G/4G Network Orchestration System (NOS). 3GPP Standards define how maximum allowed transmit power may be controlled. 3GPP TS25.331 V12.1.0 (2014-13) at Section 8.6.6.8 addresses maximum allowed transmit power. The maximum transmit power is defined as the lower of the maximum output power of the mobile device power class and the maximum allowed transmit power indicated by the controlling picocell onboard the aircraft, which shall not be

exceeded. Thus, as a function of the picocell instruction and the air interface standard, mobile devices onboard the aircraft cannot transmit at powers above their commanded levels.

*New/Uncovered Bands.* In addition, CTIA suggests that if the NCU does not include a particular band, then an uncovered device will transmit in an uncontrolled manner. The NCU is designed to emit a low level signal to raise the noise floor of the mobile device receives within the aircraft cabin. The frequencies at which the NCU transmits are programmable to account for variations in the spectrum used by the mobile service in different countries in the flight path. In this way, the NCU masks the pilot signal transmitted by terrestrial base stations and prevents onboard mobile devices from attempting to connect to terrestrial wireless networks at high transmit powers. AeroMobile's first generation NCU can dynamically adjust to transmit on relevant spectrum bands around the world, and its next generation NCU is designed to be even more flexible to address new mobile spectrum bands as they are brought into use in the future.

That said, certain spectrum bands potentially could be uncovered relative to legacy AAS equipment or as a result of the addition of a new frequency range for terrestrial use. AeroMobile would first note that this situation exists on passenger aircraft flying in U.S. airspace today, except that *all* bands are uncovered and *all* devices are uncontrolled. The use of AAS technology substantially improves this situation by covering major spectrum bands and controlling handsets to their lowest power state. In addition, transition periods to replace legacy radio equipment are commonplace, and the need for appropriate transition periods in the aviation context is even more critical given the long lead-times for equipment development and retrofit.<sup>19</sup>

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<sup>19</sup> This is the primary reason that the EU provided a significant transition period in its updated IMC standard – to afford a reasonable period for continued operation of installed base of equipment and upgrade over time.

AeroMobile would also note that terrestrial deployment in new frequency bands is an incremental process, with base station activation, equipment availability and subscriber activation occurring over time. Thus, the potential for interference from uncontrolled operations in new or uncovered bands is related to the extent of terrestrial deployment and mobile device availability in such bands. This situation is further mitigated by the multi-band nature of new mobile devices that can connect to the AAS (and thus be controlled) in other available bands. Regulators and standards bodies around the world are already mindful of terrestrial spectrum developments in updating IMC standards and, consistent with its own policies and precedent, the Commission should facilitate appropriate transitional arrangements for AAS equipment subject to the fundamental principal that IMC operations shall not cause harmful interference to other systems and services in the United States.

*Impact on Multiple Uses and Innovative Sharing Regimes.* Finally, CTIA implies that IMC operations would have a detrimental impact on innovative sharing regimes and other uses of the band. This assertion could not be farther from the truth – IMC is, itself, an additional use of spectrum based on an innovative sharing regime that has been implemented globally. Given their unique operational circumstances, including extremely low power transmissions and large separation distances from potentially affected receivers, IMC operations can share with a many other systems and services. Indeed, transmissions are effectively confined to the vicinity of the aircraft and are akin to the levels associated with Part 15 unlicensed devices.

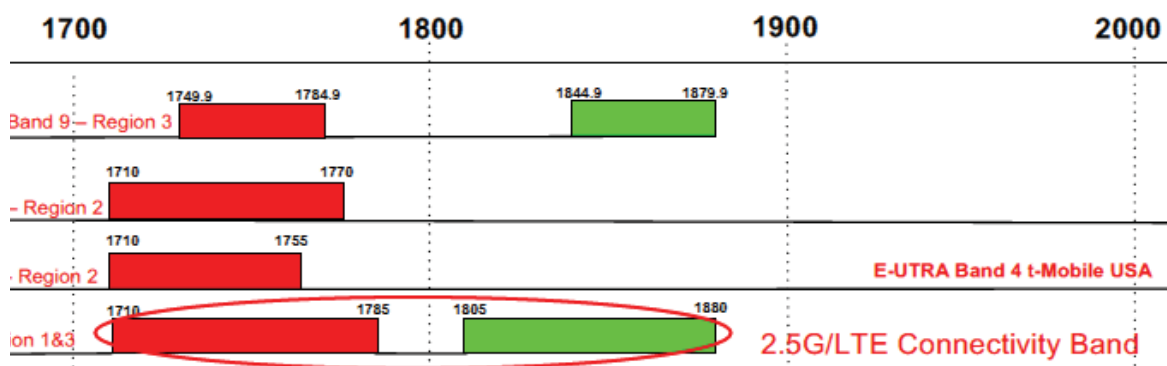
Extending the reach of terrestrial wireless networks into the aircraft cabin using AAS technology has proven to be compatible with a wide variety of systems and services around the world – and all available analyses confirm that this will also be true in the United States.

Additional interference assessment issues raised in the context of AeroMobile’s recent consultations with CTIA are set forth in the attached supplemental Technical Appendix.

## 2. AAAs Can Operate in the 1800 MHz Band Without Adversely Affecting U.S. Government Operations

As the Commission is aware, in order to bring the benefits of IMC to the United States, AASs should be permitted to operate in the 1800 MHz band. Today, existing AAS picocells utilize the 1800 MHz GSM band (1710-1785 MHz (uplink) and 1805-1880 MHz (downlink)) for connectivity with onboard mobile devices. Pursuant to the updated standard, next-generation picocells – which may be brought into operation later this year – will also operate LTE in the foregoing 1800 MHz bands, as well as UMTS at 2100 MHz (1920-1980 MHz (uplink) and 2110-2170 MHz (downlink)). In order to enable legacy and next-generation AAS systems to operate in the United States, access to the 1800 MHz connectivity band (depicted below) should be permitted within the aircraft cabin.

**Figure 2. 1800 MHz Connectivity Bands**



However, certain concerns regarding the potential impact of IMC operations on U.S. government systems and services must be addressed.

**a) IMC Picocell and Mobile Device Operations Would Not Cause Harmful Interference to Other Users of the 1800 MHz Band**

Extensive international technical studies, as well as AeroMobile's previous technical submission in this proceeding, establish that IMC operations will have no adverse impact on terrestrial wireless systems and services. The very low power mobile device uplink transmissions and picocell downlink transmissions onboard the aircraft, as well as large separation distances between IMC-equipped aircraft at cruise altitude and U.S. government systems, confirms that IMC operations will have no adverse interference impact on those systems. It is not possible to fully quantify the potential interference impact of limited IMC operations onboard international flights on all U.S. government systems operating in the 1800 MHz band because, among other reasons, the receiver sensitivity and other operational characteristics of these systems are not publicly available. However, AeroMobile is in dialogue with the National Telecommunications and Information Administration ("NTIA"), the U.S. Department of Defense ("DoD") and representative of the spectrum offices of military services with assignments in the 1800 MHz band to fully assess relevant spectrum compatibility issues.

In this connection, it is important to note that the sharing scenario between IMC operations and U.S. government operations in the 1800 MHz band differs dramatically from the sharing scenario examined by the Commerce Spectrum Management Advisory Committee ("CSMAC") with respect to sharing between government and commercial users in the 1755-1850 MHz band. Specifically, the CSMAC examined U.S. government sharing with extensively deployed, intensely utilized terrestrial LTE networks rather than low-power, in-flight IMC operations. The deployment densities of terrestrial LTE network, including high-power base stations and associated mobile device operating at high transmit powers, established that sharing

would be extremely difficult if not practically impossible.<sup>20</sup> This was particularly true of U.S. government airborne operations examined by CSMAC Working Group 5.<sup>21</sup>

The transmission characteristics associated with IMC operations are significantly different than terrestrial LTE networks. In particular, onboard picocells operate at very lower power given the short distances within the aircraft cabin, and associated mobile devices are commanded to their lowest power state. In addition, there is no possibility of power aggregation onboard an individual aircraft because the transmission schemes do not allow for simultaneous transmission on the same frequency. Finally, separation distances between equipped aircraft are extremely large (measured in tens if not hundreds of miles) and disparate frequency selection among various IMC equipped aircraft means that there is no possibility of multi-aircraft aggregation.

As a result, from an interference standpoint, transmissions on an IMC-equipped aircraft would look like a single low-power mobile device (on a 200 kHz GSM uplink, or a 5 GHz LTE uplink, once deployed, in the 1710-1785 MHz band) and a single, even lower-power picocell downlink with similar bandwidth in the 1805-1880 MHz band. In addition, these low-power transmissions would be within the cabin of an aircraft that is traveling at 500 mph+ at cruise altitude along well-traveled commercial air routes and away from the segregated airspace of government airborne systems (e.g., air combat training and precision guided munition systems).

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<sup>20</sup> See generally <http://www.ntia.doc.gov/report/2012/assessment-viability-accommodating-wireless-broadband-1755-1850-mhz-band>.

<sup>21</sup> Commerce Spectrum Management Advisory Committee Working Group 5, 1755-1850 MHz Airborne Operations, *Air Combat Training System, Small Unmanned Aircraft Systems, Precision-Guided Munitions, Aeronautical Mobile Telemetry*, Final Report (Mar. 4, 2014), available at [http://www.ntia.doc.gov/files/ntia/publications/wg5\\_final\\_report\\_posted\\_03042014.pdf](http://www.ntia.doc.gov/files/ntia/publications/wg5_final_report_posted_03042014.pdf) and subworking group reports.

**b)      The Potential Interference Impact of IMC Operations Would  
Be *De Minimis* and Similar to that of Part 15 Devices**

The extremely low-power nature of mobile device and picocell operations in the 1800 MHz band, as well as NCU operations in other bands, can be correlated to the power levels associated with devices operating under the Commission's Part 15 unlicensed device rules. Because they create a *de minimis* potential for interference to other systems and services, Part 15 allows certain low-power radio equipment to be manufactured and operated in the United States without a license and without limitation on the number or location in which they operate, subject to specified power level restrictions and certification requirements. Part 15 power levels generally must be satisfied at a distance of three meters from the antenna, although Part 15 also includes provisions to accommodate the operation of certain higher power equipment with a similarly low potential for interference.<sup>22</sup>

Although IMC operations do not satisfy Part 15 power levels at three meters, they do satisfy the Part 15 levels in close proximity to the aircraft. The calculations below establish the Part 15 compliance distances for 1800 MHz picocell transmissions, NCU transmissions in other bands, and 1800 MHz mobile device transmissions.

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<sup>22</sup> See, e.g., 47 C.F.R. § 15.256.

**Figure 3. Part 15 Compliance Distances**

<b>Normal Operational RF Power from CRFMU and BTSRFU</b>							
	<b>BTS TX (GSM1800)</b>	<b>800MHz</b>	<b>1900MHz</b>	<b>2100MHz</b>	<b>a-MS (Note 6)</b>		
Frequency (MHz)	1800	800	1900	2100	1800	MHz	
a-MS Power (measured in 200KHz)					0	dBm	
CRFMU Power (measured in Note 2)	23.00	25.00	17.00	20.00	-	dBm	Note 2
CRFMU 2 ACU Cable Losses	0.30	0.21	0.30	0.35	-	dB	
ACU Loss	15.15	1.55	7.00	1.20	-	dB	
ACU to Leaky Feeder Losses	0.98	0.55	0.78	0.88	-	dB	
Connector Losses	1.60	1.60	1.60	1.60	-	dB	
Input Power into LF	4.97	21.09	7.32	15.97	-	dBm	
Input Power into LF (Watts)	3.14E-03	1.29E-01	5.40E-03	3.95E-02	1.00E-03	Watts	
a-MS Antenna Gain					0	dBi	
LF Antenna Gain Start	-13	-16	-13	-13	-	dBi	
LF Gain Mid Aircraft	-18	-22	-18	-18	-	dBi	
LF Antenna Gain End (50mtrs)	-23	-27	-23	-23	-	dBi	
Aircraft Fuelage Attenuation	-10	-10	-10	-10	-2	dB	Note 3 , Note 4
Distance to Leaky Feeder Dm	24.4	246.6	32.0	86.7	275.2	m	
Field Strength from Start of LF Cable at Distance (D)	889	399	889	889		µV/m	
<b>Field Strength at Mid of LF Cable at Dista</b>	<b>500</b>	<b>200</b>	<b>500</b>	<b>500</b>		µV/m	Note 5
Field Strength at End of LF Cable at Distance (Dm)	281	112	281	281		µV/m	
<b>Field Strength at Distance (Dm) from a-MS</b>	-	-	-	-	500		
Part 15 3Mtrs Note 1	500	200	500	500	500	µV/m	Note 1

Note 1: 216-960MHz 200µV/m > 960MHz 500µV/m measured at 3mtrs Part 15.209 Radiated Emissions Limit (General Requirements)  
 Note 2: All RF Powers are measured in 200KHz B/W for the BTS and the NCU bandwidths ( 25MHz - 800MHz, 1900MHz - 60MHz, 2100MHz - 60MHz)  
 Note 3: This is taken from the ECC Report 093 Table 13 Case B for Leaky Feeder isolation.  
 a-MS Aircraft Isolation is assumed to be 2dB as a conservative value.  
 Note 4: Ground measurement of A340 aircraft isolation  
 Note 5: Mid-Point of Leaky Feeder is used for Part 15 (used for ECC Rep 093)  
 Note 6: The Antenna Gain is a maximum of 0dBi for a MS (taken from ECC Rep 093) Leaky Feeder, C Rows are not applicable

As can be seen in the figure above, the 1800 MHz picocell transmissions comply with Part 15 levels at approximately 25 meters from the antenna (or within the wingtips of the aircraft) and 1800 MHz mobile device transmissions comply with Part 15 levels at approximately 275 meters from the antenna.<sup>23</sup>

It is extraordinarily unlikely that a victim receiver will be in such close proximity to an IMC-equipped aircraft at cruise altitude traveling 500 mph+ along commercial air corridors. Recall, as well, that Part 15 establishes power levels at the Commission has determined, as a

<sup>23</sup> Because there are no terrestrial base stations operating downlinks in the 1800 MHz band, the NCU will not operate in this band in the United States. NCU transmissions in other bands also comply with Part 15 levels at similarly short distances from the transmitter.

matter of spectrum policy, that unlicensed devices may operate without causing interference to co-frequency systems and services – and the 1800 MHz band is specifically included in the frequencies identified for use by unlicensed devices. IMC equipment’s compliance with Part 15 power levels within a short distance from the aircraft and the limited number of international flights at issue confirm that IMC operations can be conducted on a non-interference basis in the 1800 MHz band.

**c) At a Minimum, the Commission Should Permit Mobile Device Uplinks in the 1755-1780 MHz Band**

In view of the *de minimis* interference impact of IMC operations, the Commission should permit IMC systems, including picocells and associated mobile devices, to operate throughout the 1800 MHz band. Because these devices will operate on a non-interference basis pursuant to licenses issued by an airline’s registering nation (and pursuant to Part 15 rules on U.S.-registered aircraft), the Commission need not limit the spectrum that may be accessed by IMC systems based on its federal or non-federal government allocation status. Rather, since the Commission need not license IMC operations as a commercial service, it may permit access to the 1800 MHz band on an unprotected, non-interference basis like Part 15 devices.

However, if the Commission concludes that a non-federal allocation is necessary to support IMC operations, or if concludes that AASs on U.S. aircraft should be authorized pursuant to a license by rule approach rather than a Part 15 approach, then AeroMobile suggests that it should be possible to limit mobile device uplinks in the 1755-1780 MHz band and paired picocell downlinks in the 1850-1875 MHz band. The 1755-1780 MHz sub-band is currently allocated in the United States for both commercial and federal government use (although other

portions of the 1755-1850 MHz band remain under consideration for reallocation)<sup>24</sup> and the paired downlink is above 1850 MHz and outside of the current exclusive federal government allocation.

The GSM and LTE air interfaces permit AASs and associated mobile devices to operate in a subset of available 1800 MHz band (particularly using GSM technology, where only one or two 200 kHz channels are employed). Restricting 1800 MHz AAS operations to the frequencies identified above would ensure that low-power mobile device uplinks operate only in spectrum currently allocated for shared use but identified for transition to exclusive commercial use in the future. This, in turn, would significantly limit the potential impact of AAS operations on U.S. government systems. Although AeroMobile believes that such a limitation would be unnecessary given the non-interfering nature of IMC operations and may constrain available bandwidth for IMC applications onboard aircraft, this approach would involve only a temporary overlap with U.S. government operations and ensure that IMC is permitted in bands that will ultimately be allocated for exclusive commercial use.

### **C. The Commission Should Expediently Enable Operation of AASs on International Flights in the United States**

The most effective and expeditious method for the Commission to enable international IMC operations is to recognize the authority granted to foreign airlines by their licensing administrations as a matter of FCC policy. This approach is appropriate in the context of limited

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<sup>24</sup> See Boeing Comments at 15 (“Given the significant advantages of maintaining continuity of service for such systems, as well as the benefits of offering a single AAS capable of serving both U.S. and international markets, Boeing recommends that the Commission adopt its proposal to make the 1755-1780 MHz band available for shared Federal and non-Federal use, and to permit AAS operations in this band.”).

international IMC operations because AAS technical standards are well-established and AAS equipment is certified under extensive civil aviation procedures to comply with such standards.

Because any rules for international IMC services would necessarily embody these international IMC standards, recognizing existing operating authority would be consistent with the protection of potentially affected services in the United States, and with the approach adopted by many countries around the world in accordance with generally accepted principles of international civil aviation. To the extent a more formal, rules-based approach is deemed appropriate and to support IMC operations on U.S. aircraft serving international routes, AeroMobile believes that the Commission should modify Part 15 of the rules to permit AASs to operate on an unlicensed basis.

**1. The Commission Can Permit AAS Operation in U.S. Airspace by Recognizing Foreign AAS Authorizations**

The Commission expressly raised the issue of international license recognition in the *NPRM*. In response to the Commission’s query whether “it is in the public interest to allow aircraft authorized by a foreign government to provide mobile communications services to continue operating its Airborne Access System within U.S. airspace and thereby provide uninterrupted airborne mobile communications services to its passengers,”<sup>25</sup> AeroMobile offers a resounding “Yes!”— and the Commission should do so simply by giving notice that it will permit operation of AAS equipment that conforms to existing standards pursuant to authorization issued by foreign regulatory bodies. In doing so, the Commission would recognize the validity of the extensive body of interference studies and operational experience that indicate no issues associated with the equipment of AAS equipment that conforms to these international standards.

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<sup>25</sup> *NPRM* at ¶ 64.

AeroMobile agrees with Aviation Spectrum Resources, Inc. (“ASRI”), who encouraged the Commission to examine its discretion under the Chicago Convention to authorize foreign airlines to operate an AAS within U.S. airspace. Although the Commission may not be required to recognize foreign AAS licenses under U.S. law, the Chicago Convention certainly does not prevent the FCC from recognizing foreign AAS licenses or allowing reciprocity for existing AAS operations.<sup>26</sup> AeroMobile believes that Commission recognition of foreign airline AAS licenses would, at a minimum, be consistent with the legal principles embodied in the Chicago Convention and would avoid a duplicative licensing framework for foreign airlines, particularly in light of the broad international recognition afforded aircraft licenses around the world.<sup>27</sup>

Additionally, a decision to recognize foreign AAS licenses would be consistent with established principles of international commercial aviation. As noted above, the technical parameters for AAS operations are based on international standards set forth the ECC of the EU CEPT, and AASs have operated on non-U.S.-registered aircraft worldwide without incidence of interference. Commission action to recognize these licenses would give immediate authority to these airlines to operate AASs and would avoid the redundancy of licensing these systems.

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<sup>26</sup> As noted by ASRI, Article 33 provides that foreign States licenses will be recognized as valid by member nations where the “requirements under which such . . . licenses were issued . . . are equal to or above the minimum standards which may be established from time to time pursuant to [the Chicago Convention].” *See* ASRI Comments at 5-6. This principle may be extended to other standards adopted in the international aviation context.

<sup>27</sup> To the extent the Chicago Convention is not considered a basis for international license recognition, Article 18 of the ITU Radio Regulations establishes that an aircraft’s registering nation is responsible for aircraft station licensing and provides an independent basis for license recognition. Moreover, it is unclear that Section 303(f) of the Communications Act contemplates FCC licensing jurisdiction over equipment confined entirely within a foreign aircraft cabin that is subject to the jurisdiction of a foreign licensing administration. AeroMobile submits nonetheless that, like regulators from other nations around the world, the Commission has discretion to recognize foreign aircraft licenses under international treaty principles.

Should the Commission choose not to recognize the licenses, it should nevertheless avoid applying disparate technical requirements to existing AAS operations on foreign airlines. AAS equipment operates according to existing technical parameters that have been standardized in jurisdictions worldwide and accepted in the United States by the FAA for certification purposes. AeroMobile respectfully submits that it is incumbent upon the FCC to allow airlines to operate in accord with their existing licenses and certifications. Regulation that fails to accommodate accepted standards effectively would prohibit IMC operations within U.S. airspace, which would be contrary to the Commission's efforts to bring the benefits of IMC to the U.S. traveling public.

## **2. Part 15 Provides a Viable Basis for IMC in the United States**

To the extent necessary to support IMC operations on international flights of U.S. and foreign aircraft present in U.S. airspace, AeroMobile believes the Commission should adopt rules incorporating existing international standards in Part 15 of its rules. As discussed above, IMC involves the extension of a wireless carrier's mobile broadband service to subscribers who are traveling onboard aircraft through the use of AAS technology. Part 15 is an appropriate section of the rules to include technical standards governing the operation of low-power equipment that is simply used to connect terrestrial wireless carriers to their subscribers who are traveling onboard aircraft in flight.

The Commission recently adopted new Part 15 rules for level probing radars ("LPRs") that, like AASs, do not strictly comply with existing Part 15 power level requirements but have a similarly *de minimis* potential for interference to other spectrum users.<sup>28</sup> Moreover, like AASs,

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<sup>28</sup> See *Amendment of Part 15 of the Commission's Rules to Establish Regulations for Tank Level Probing Radars in the Frequency Band 77-81 GHz, Amendment of Part 15 of the Commission's Rules to Establish Regulations for Level Probing Radars and Tank Level Probing Radars in the Frequency Bands 5.925-7.250 GHz, 24.05-29.00 and 75-85 GHz*, ET Docket 10-23, Report and Order (FCC 14-2) at ¶ 11 (rel. Jan. 15, 2014).

LPRs operate pursuant to technical standards developed in Europe, use spectrum bands different from those typically utilized in the United States, and are not sold to the public for consumers use but rather operate in controlled circumstances. The Commission’s decision to harmonize Part 15 rules with European standards for LPR operations provides direct and compelling precedent for a similar approach to facilitate AAS operations in the United States.

AeroMobile would note that Part 15 rules governing AAS operations could be expanded to include U.S. domestic IMC operations. Once interested parties have had an opportunity to conduct further work on domestic IMC implementation, the Commission could amend the rules to allow for AAS operations onboard U.S. domestic flights. The Commission also could supplement Part 15 technical rules with a Part 87 license for U.S. aircraft only if considered necessary to ensure AAS operating authority for U.S.-registered aircraft traveling in international and foreign airspace.<sup>29</sup>

### **3. In Any Event, the Commission Need Not Require IMC Providers to Comply with Part 20 CMRS Rules**

The Commission seeks comment on whether IMC providers should “be required to comply with all rules applicable to CMRS [commercial mobile radio service] licensees under Part 20 of the Commission’s rules given the limited scope of the in-cabin service offering.”<sup>30</sup> Because AASs equipment simply extends mobile connectivity to consumers traveling onboard airborne aircraft, AeroMobile believes such service-related rules are neither appropriate nor required. Furthermore, AeroMobile submits that the Commission may lack jurisdiction to

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<sup>29</sup> AeroMobile believes, however, that Part 15 authority would travel with the equipment by virtue of FCC jurisdiction over radio operations onboard U.S.-registered aircraft and thus would afford U.S. airlines with sufficient AAS operating authority outside the United States.

<sup>30</sup> *NPRM* at ¶ 57.

impose such requirements within a foreign aircraft cabin and, even if such jurisdiction exists, it would be contrary to FCC policy and the public interest.

In every case, the Part 20 rules governing CMRS providers would be either inapplicable to IMC operations, or would be met by the passenger's chosen home CMRS provider. For example, E-911 requirements simply make no sense in an airborne emergency. Passengers have immediate access to cabin crew members, who are considered first responders aboard an aircraft<sup>31</sup> and who are trained to respond to in-flight emergencies. Those crew members are also best able to consult with specialists on the ground, using the primary aviation radio communication channels, if needed. For this reason, AeroMobile's IMC services automatically provide directions to any passenger dialing "911" to contact a member of the cabin crew.

Customer Proprietary Network Information ("CPNI") obligations are similarly inapplicable to IMC providers, because IMC providers are neither carriers nor affiliates or marketing agents of the carriers.<sup>32</sup> The Communications Act of 1934, as amended, defines CPNI, in relevant part, as "information that relates to the quantity, technical configuration, type, destination, location, and amount of use of a telecommunications service subscribed to by any customer of a telecommunications carrier, and that is made available to the carrier by the customer solely by virtue of the carrier-customer relationship."<sup>33</sup> As discussed herein, the IMC provider is not a telecommunications carrier, and the air passenger is not its customer. Rather, the passenger's home CMRS provider will remain bound by CPNI obligations, including with

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<sup>31</sup> See Association of Flight Attendants-CWA, AFL-CIO Comments at 2.

<sup>32</sup> 47 C.F.R. § 64.2007(b).

<sup>33</sup> 47 U.S.C. § 222(h)(1)(A).

respect to the passenger's use of IMC service. Thus, the Commission should recognize that there is no need to extend CPNI obligations in this context.

Similarly, the Commission's rules require CMRS carriers (and other telecommunications carriers) to contribute to universal service support mechanisms, as well as the Commission's funds supporting telecommunications relay service ("TRS"), administration of the North American Numbering Plan, and the shared costs of local number portability administration.<sup>34</sup> IMC providers have no retail end user telecommunications customers, and do not operate on a common carrier basis. As stated by the United States Court of Appeals for the District of Columbia Circuit, the "primary *sine qua non* of common carrier status is a quasi-public character, which arises out of the undertaking to carry for all people indifferently."<sup>35</sup> As an IMC provider, AeroMobile makes no such undertaking -- it provides service only on a private contractual basis to CMRS providers within an international roaming framework and it bears no legal obligation to serve all of its CMRS provider-customers indifferently.<sup>36</sup> Rather, the passenger's home CMRS provider, as the owner of the end user relationship, bears the obligation

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<sup>34</sup> *1998 Biennial Regulatory Review – Streamlined Contributor Reporting Requirements Associated with Administration of Telecommunications Relay Services, North American Numbering Plan, Local Number Portability, and Universal Service Support Mechanisms*, CC Docket No. 98-171, Report and Order, FCC 99-175, 14 FCC Rcd 16606 (1999), at ¶ 6.

<sup>35</sup> *National Ass'n of Regulatory Util. Comm'rs v. FCC*, 533 F.2d 601, 608 (D.C. Cir. 1976) ("*NARUC II*") (internal quotation marks omitted).

<sup>36</sup> Even if viewed as telecommunications providers, IMC revenues would be unlikely to trigger universal service contribution obligations. Contributions are based on a telecommunications carrier's interstate (and U.S. international) end-user, telecommunications revenue, 47 C.F.R. § 54.706(b). IMC providers have no end user customers because they solely provide wholesale access services to retail CMRS providers using an international roaming framework. Thus, their contribution base would necessarily be zero, based on this criterion alone.

to properly classify and report the revenue it receives from its customer based on his or her use of IMC services.

Moreover, because IMC includes broadband Internet access and data services, at least a portion of an IMC offering constitutes an information service, not telecommunications, which is exempt from the contribution requirement.<sup>37</sup> Finally, because IMC is provided using an international roaming framework, all communications can be considered to originate outside the U.S., and many, of course, also terminate in foreign countries. As a result, existing IMC operations, which are global in nature, are likely to qualify for the international revenue / 12 percent rule or the *de minimis* USF contribution exemptions.<sup>38</sup>

#### **4. IMC Providers Have Accepted CALEA Obligations and Would Be Willing to Address Security Issues through Individual Negotiations**

In the *NPRM*, the Commission sought comment on additional measures the agency should take to address in-flight safety and security concerns beyond Communications Assistance for Law Enforcement Act (“CALEA”) obligations and individual agreements among IMC service providers and law enforcement agencies. The record in this proceeding universally reflects the airborne mobile communications industry’s acceptance of CALEA obligations and willingness to address surveillance and security concerns through individual negotiations with law enforcement agencies.

Satellite providers, earth stations aboard aircraft (“ESAA”) operators, and 800 MHz air-ground licenses continue to work with law enforcement agencies to develop individual

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<sup>37</sup> See *Appropriate Framework for Broadband Access to the Internet Over Wireline Facilities*, CC Docket No. 02-33, Report and Order, FCC 05-150, 20 FCC Rcd 14853 (2005), at ¶ 12 (“*Wireline Broadband Internet Access Order*”). Thus, many of the obligations discussed in this section would apply solely to voice services provided via IMC.

<sup>38</sup> 47 C.F.R. §§54.706(c), 54.708.

agreements and implement appropriate solutions to public safety concerns.<sup>39</sup> In its comments, the Telecommunications Industry Association (“TIA”) argued that the Commission should apply a similar approach to proposed IMC operations.<sup>40</sup> Boeing also supported this course of action and noted that “current system [of CALEA obligations and individual negotiations] is adequate and flexible enough to address any new considerations.”<sup>41</sup> AeroMobile agrees with these commenting parties and has consulted with U.S. law enforcement on numerous occasions to coordinate public safety and security needs.

### **III. Conclusion**

For the foregoing reasons, AeroMobile urges the Commission to expeditiously authorize AAS operations on U.S. and foreign-registered aircraft operating on international routes pursuant to existing standards, reject service-related requirements for IMC providers, and afford interested parties additional time to develop recommendations for implementation of IMC on U.S.

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<sup>39</sup> *NPRM* at ¶ 77.

<sup>40</sup> *See* TIA Comments at 11.

<sup>41</sup> *See* Boeing Comments at 14.

domestic flights. In this way, consistent with fundamental principle of compatibility with other U.S. systems and services, the Commission will bring the significant benefits of in-flight mobile broadband to U.S. consumers at the earliest practicable time.

Respectfully submitted,

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## TECHNICAL APPENDIX

ECC Report 93 is a Technical Report of the ECC considering compatibility between GSM equipment on board aircraft and terrestrial networks. It considers GSM connectivity on board the aircraft in the 1800MHz band (3GPP Band 3). ECC Report 187 is a technical Report of the CEPT ECC considering mobile communication services on board aircraft (MCA) and ground-based systems. It considers UMTS connectivity on board the aircraft in the 2100MHz band (3GPP Band 1), and LTE connectivity on board the aircraft in the 1800 MHz band.

The technical parameters used in the ECC analysis was derived where possible from recognized ITU and 3GPP standards for base station, user equipment and antenna characteristics, as well as, where appropriate, from real life 'operational' parameters provided by the technical experts from the mobile network operators and equipment vendors contributing to the studies.

These reports are used as the technical basis for harmonized regulatory frameworks in Europe and in Asia, and for domestic regulatory frameworks to enable MCA services worldwide – including in ITU Region 2, the Americas.

### **Stakeholder Participation**

In 2011, Working Group Spectrum Engineering (SE) 7 was tasked to update the compatibility studies in ECC Report 93 to include the new frequency bands. During the course of the development of the studies within WG SE7, various stakeholders were present and contributed technical details for discussions and for the studies. Like the technical studies that supported the original standards development, the meeting responsible for accounting for all stakeholder perspectives used agreed technical details and conclusive results of the analysis were included in the final technical report.

Participation by U.S. interests in the European standards development was limited, but equipment manufacturers, wireless carriers, aviation interests and various government agencies were directly involved. More recently in the United States, in response to the FCC's NPRM, AeroMobile engaged with U.S. domestic stakeholders, including wireless carriers and U.S. government interests, to provide further background on the technical studies and regulatory frameworks for MCA internationally. In support of that activity, the following additional technical issues were discussed.

### **Technical development and discussions**

- 1) On developing the worst case antenna elevation angle from the ground g-BTS/NodeB in the direction of the aircraft

In order to study the worst case scenario to determine the most stringent technical requirement on protecting the ground network, SE7 has used the following method as used in the previous ECC Report 93. The ECC calculated the interference level ( $I_{g-BTS\_to\_ac-MS}$ ) received by ac-MS/UE from g-BTS/NodeB using the following equation:

$$P_{rec\_ac-MS} = EIRP_{g-BTS} - L_{prop} - L_{Aircraft} + G_{ac-MS} \text{ (dBm)}$$

Where

$EIRP_{g-BTS}$  : e.i.r.p. of the signal radiated by the g-BTS/NodeB, in the direction of the aircraft. It already considers the antenna gain, which follows the ITU F.1336, Peak, as described in section 6, (dBm)

$L_{prop}$  : Propagation Loss between g-BTS/NodeB and the aircraft (dB)

$L_{Aircraft}$  : Attenuation due to the aircraft (dB)

$G_{ac-MS}$  : Antenna gain of the ac-MS/UE, (dBi)

The resulting margin at the ac-MS/UE receiver is given by:

$$M = Sens_{rec} - P_{rec\_ac\_MS} \text{ (dB)}$$

$Sens_{rec}$  : Receiver sensitivity (dBm)

$P_{rec\_ac\_MS}$  : Received power at on board ac-MS/UE (dBm)

Using these equations, the worst case elevation angle at 800 MHz is 48° for aircraft from 3000 m height. The relative antenna gain is -0.34 dBi. For 2GHz, the relative antenna gain is -1.84 dBi with the worst elevation angle at 48°.

Report 93 also concluded that difference in margin between 2.0 degree and 48 degree at 2 GHz is only 0.06 dB (17.42 dB - 17.36 dB = 0.06 dB). The final conclusions of CEPT Report 48 would not change by using a value other than 48°.

## 2) The orientation of the ground mobile network antenna

In general, for mobile network deployment, the antenna is placed high-enough to cover a large area with a downtilt. The deployment of cellular networks may differ slightly in different areas, and it is understood that in certain deployment scenarios the antenna may be uptilted to provide coverage within skyscrapers, other tall structures and mountainsides. However, in such circumstances the antenna may be screened by the building / mountain to be covered or uptilt is otherwise mitigated by other factors (e.g., aircraft motion at cruising speed, which makes worst case geometry temporary and fleeting). As a result, we do not consider that this specific deployment scenario to be representative of any interference risk not already accommodated by the ECC studies.

### 3) Attenuation due to Aircraft, or “aircraft attenuation” or “attenuation due to the fuselage”

The attenuation due to the aircraft is considered in Section 6.5 of Report 93, and describes how different values of attenuation used in the ECC modelling were derived. The 5dB attenuation considered for the aircraft attenuation is a value obtained from the measurement campaigns referenced in Appendix C of Report 93.

In summary, for the purposes of ECC Report 93 and Report 187 the "attenuation due to the aircraft" aims to express the difference in dB, between either:

- the field radiated (or received) by a mobile in free space and from (or to) a mobile within an aircraft (ac-MS signal attenuation in Table 13), or
- the field radiated by a leaky feeder in free space and from an aircraft with the same leaky feeder within it (ac-BTS/NCU, connected to a leaky feeder, signal attenuation in Table 13),

Different measurement campaigns were made and have been analysed and the results were found to be quite heterogeneous. The different Annexes of ECC Report 93 provide greater technical detail on how these values were derived, and include in:

ANNEX B – a description of approaches used for analysing the terrestrial RF effects of the onboard leaky feeder, including in Annex B.2, a comparison of measurement data with a theoretical analysis of the possible array-effect of the leaky feeder antenna radiating out of the fuselage windows.

ANNEX C - a summary of the measurement campaigns considered.

ANNEX F - a description of the effectiveness of aircraft RF shielding and the subsequent impact of the ability for an airborne mobile to acquire terrestrial CDMA networks.

The results of the different measurements and analyses show the attenuation of the RF signal by the aircraft varies with both horizontal and vertical angle between the aircraft fuselage and the line of sight to the observation position.

The results provided are not based on angle-dependency of attenuation, but instead a range of non-angle dependent values considered (by IMC providers, terrestrial mobile operators, equipment vendors, and the national regulatory authorities within the CEPT) to capture the variation of the actual figures.

The values used in the analysis considered in ECC Report 93 and Report 197 are characterised as follows:

Case	Ac-MS signal attenuation	Ac-BTS/NCU signal attenuation
A (low)	1	5
B (medium)	5	10
C (high)	9	15

These values correspond to those in Table 13 of Report 93.

ECC Report 93 and Report 187 considered two modelling methodologies to determine the extent of potential interference to terrestrial mobile systems from MCA operations. These are:

- Minimum coupling loss (MCL) calculations, and
- Monte Carlo simulations

For the MCL calculations, cases A, B and C were used as the reference attenuation case.

For the SEAMCAT analysis, Case B was used as the reference attenuation case. However, given the variation of values in aircraft attenuation, sensitivity analysis was undertaken for each of the relevant (SEAMCAT) scenarios as follows:

Scenarios 3 (NCU and ac-BTS => terrestrial network downlink) and Scenario 4 (multiple aircraft NCU and ac-BTS => terrestrial network downlink): Sensitivity analysis of -9 dB (Case A: reduced attenuation) and + 9 dB (Case C: increased attenuation). This corresponds to the combination of the attenuation due to the aircraft of the terrestrial signal entering the cabin (+/- 4 dB) and the attenuation due to the aircraft of the signal from the ac-BTS/NCU leaving the aircraft (+/- 5 dB);

Scenarios 5 (ac-MS => terrestrial network uplink) and Scenario 6 (multiple ac-MS => terrestrial network uplink): Sensitivity analysis of -4 dB (Case A: reduced attenuation) and + 4 dB. (Case C: increased attenuation). This corresponds to the attenuation due to the aircraft of the signal from the ac-MS leaving the cabin (+/- 4 dB).

The sensitivity analysis conducted in these scenarios revealed no material differences in results and, thus, that the values in Table 13 of Report 93 are representative of fuselage attenuation effects.

- 4) Radiation Factor for calculating the NCU power required and resultant impact on terrestrial systems and the Masking Factor

In assessing the total power inside the aircraft cabin, the aircraft fuselage was considered to be a cylinder with radius R and Length L, corresponding approximately to the real dimensions of the aircraft considered. The electric field strength received by an ac-MS close to the fuselage window or wall was denoted by  $P_{\text{Target}}$ . Based on this, the total power needed to cover the whole cabin, or the surface of the 'cylinder' in the model,  $P_{\text{cylinder}}$  was calculated. The difference between the two levels is defined as the Radiation Factor.

It was assumed that the NCU or ac-BTS generates a quasi-uniform electric field on the internal side of the cylinder, i.e. a uniform power flux density ( $\text{W}/\text{m}^2$ ) on the internal surface of the aircraft. The model also considered that the power is radiated by the side area of the cylinder. The total power of the electric field inside the aircraft is then calculated as the power flux density multiplied by the side area of the cylinder. This is how the 64dB figure was derived. Further explanation is provided in Section 7.5.2 of ECC Report 93.

The ECC Report 93 and 187 further considered additional NCU margin. This is represented by the term "masking factor" as described in Section 6 of Report 93. The masking factor is defined as the ratio by which the inserted noise has to exceed the received terrestrial signals in order to remove visibility of terrestrial networks from within the cabin, and values up to 21dB were considered.

This analysis demonstrated the additional masking factor up to 21 dB reliably shielded onboard mobile receivers from terrestrial base station signals but was not high enough to cause interference to the terrestrial network.

## 5) RF characteristics of a leaky feeder

ECC Report 93 and Report 187 recognize that both the NCU and ac-BTS output powers and EIRP (inside the aircraft) may increase with aircraft size; and may decrease as the operational height increases. Consequently, a large aircraft was used for single aircraft analysis. For multiple aircraft analysis, an average power was assumed based on the distribution of the aircraft described in Section 6.9 of ECC Report 93. The lower aircraft height and, the higher the NCU power needed to prevent ac-MS/UE from receiving terrestrial signals, and consequently the ac-BTS power must also be increased. With higher radiated power, the risk of interference to terrestrial networks is higher. The risk of interference therefore decreases when the minimum height of the aircraft is increased.

ECC Report 93 considered that the RF characteristics of a leaky feeder can be predicted assuming the 'cylinder model'. This model is based on the following assumptions:

- The aircraft radiates as an isotropic antenna; and
- The total power, in dBW, radiated by the aircraft is equal to the total power, in dBW, radiated inside the aircraft by the MCA system and acMS/UE minus the aircraft attenuation in dB.

When determining that the 'cylinder model' was a valid and reasonable assumption, the ECC considered other approaches for analysing the terrestrial RF effects of the on board leaky feeder. As mentioned above, detail of these considerations can be found in ANNEX B of ECC Report 93 but these can be summarised as follows.

### **Morgan's Approach**

ECC Report 93 compares and contrasts the results of the 'cylinder model' for modelling leaky feeder radiation with those derived using Morgan's Approach (REF: "Prediction of indoor wireless coverage by leaky feeder using coaxial cable using ray tracing", IEEE Trans Veh. Tech., Vol. 48 (6), pp. 2005-2014, Nov 1999. SP Morgan)

Using this approach, the power from the leaky feeder when a receiver was located aboard the aircraft at distance  $D \ll L$ , where  $L$  is the length of the feeder cable within the fuselage was derived. From this, the EIRP from the cable seen from the ground at a distance  $D \gg L$  was then calculated.

Generally, in order to obtain a radiated power intensity for the leaky feeder, it is first of all necessary to obtain the radiated electric and magnetic fields, which are coherent sums due to induced currents on the cable shield. However, in practice, it is impossible to determine the induced cable currents in the presence of surrounding objects, and the scattered local fields will vary randomly, so the approach used was based on incoherently radiating sources (elements of the leaky feeder) and a power sum, which does not indicate fast local variation of the radiated field: the fading pattern. A fading margin (10dB) was then added to account for local variation in the received signal.

Comparing the MCL analysis assuming the ‘cylinder model’ and ‘Morgan’s approach when considering the NCU on terrestrial networks at 1800MHz gives the following results:

Altitude (Km)	3	4	5	6	7	8	9	10
<b>Increase in noise floor at g-BTS with respect to typical values (dB)</b>								
Cylinder Model	0.1	0	0	0	0	0	0	0
Morgan’s approach	0.1	0	0	0	0	0	0	0
<b>Difference (dB)</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>

These results demonstrate that that the results of using both the cylinder model and the Morgan’s approach are well aligned.

### **Characteristics of the attenuation due to the aircraft when considering an onboard leaky feeder antenna**

The ECC Reports 93 and 187 recognizes that the assumptions on the aircraft attenuation has a significant impact on the compatibility studies between MCA and terrestrial systems. The compatibility studies also considered that the use of the leaky feeder to distribute the on board BTS signal, as well as the NCU, may have the potential to transform the aircraft fuselage, with its multiple apertures, into an array antenna with potentially high peak gain patterns.

The simplest treatment of the external signal leakage from the RF sources inside the aircraft cabin is to assume the total EIRP of the source is subject to some fixed attenuation of the aircraft, i.e. no directivity at all when the far-field is observed. The MCL and SEAMCAT compatibility studies in Reports 93 and 187 take this approach and use a range of 5-15 dB for ac-BTS and NCU attenuation by the aircraft fuselage. This range is based on the worst case average attenuation values taken from a number of measurement campaigns.

A more detailed approach was also taken to consider emissions from the leaky feeder running the length of the aircraft cabin, where the far-field leakage external to the aircraft is governed by the physical conditions inside the aircraft and the traditional RF emission characteristics. This approach considered that that the antenna theory governing RF emissions are governed by the following four principal factors:

- i. The far field emission characteristics of the leaky feeder, including coupling loss (cable attenuation) and longitudinal attenuation;
- ii. The fraction of RF energy from a segment of the leaky feeder which escapes a single fuselage window, which is the primary aperture for external signal leakage (and assumed to be equal to the fraction of total RF energy escaping from the total number of windows);
- iii. The far-field antenna pattern of a single window aperture; and
- iv. The combined far-field pattern of all aircraft windows, including phased array effects.

Based on these principal factors, the ECC concluded that it was not necessary to consider that the radiation from multiple elements of the leaky feeder combined to transform the aircraft fuselage into an array antenna.

- 6) On addressing CDMA and UMTS power control mechanism in the studies and the actual equipment control and related standards

SEAMCAT modelling software incorporates a TDMA, CDMA, and OFDMA modules. Each accounts, in significant detail, for the technical and operational differences of the different technologies.

For the CDMA simulations conducted by the ECC, the device power control was accounted for in the model. The following screenshot illustrates the ac-UE power control range may be modelled using SEAMCAT.

The screenshot shows the 'Victim Link' dialog box in SEAMCAT. The 'General' tab is active. Under 'CDMA Link component', 'Uplink' is selected. The 'Link Level Data' dropdown is set to 'W-CDMA/UMTS : QUALCOMM Europe : 835.0 MHz : uplink : 1% FER'. A red box highlights the 'Uplink Model' section, which contains the following parameters:

Parameter	Value	Unit
Target Network Noise Rise	6.0	dB
Mobile Station Maximum Transit Power	21.0	dBm
Mobile Station Power Control Range	71.0	dB
PC Convergence precision (linear)	0.1	dB

The 'Downlink Model' section is also visible, showing parameters like Base Station Pilot Channel Fraction (0.15) and Base Station Maximum Broadcast Power (21.0 dBm).

More importantly, the on board MCA system has the ability to control the maximum ac-UE transmit power.

### **AeroMobile's Equipment & Maximum transmit power control**

AeroMobile's on board system can control the UE Max Tx Power from the 3G/4G Network Orchestration System (NOS).

This done through the following parameters on the NOS:

UETxPwrMaxRACH	= Max Tx power for UE on RACH
MaxULTxPower	= Max Tx power a UE can use on PRACH (defined as a range of low and high)

Finally, 3GPP Standards define how maximum allowed UE may be controlled.

### **3GPP Standard & Maximum allowed uplink transmit power**

3GPP TS25.331 V12.1.0 (2014-13) on Section 8.6.6.8 addresses maximum allowed UL TX power

If the "Maximum allowed UL TX power" is included in the Handover to the UTRAN Command Information Element (IE), in any other dedicated message or in System Information Block type 3 or in System Information Block 4, the UE shall:

- store and use the value until it is updated.

If the IE "Maximum allowed UL TX power" was not included in any dedicated message, the UE shall:

- use the value previously stored, when received in an earlier dedicated message, Handover to UTRAN Command message or received in System Information Block type 3 or in System Information Block 4.

For all cases, the UE shall:

- keep the UE uplink transmit power at or below the indicated power value;
- if the current UE uplink transmit power is above the indicated power value:
- decrease the power to a level at or below the power value.

The maximum UE TX power is defined as the lower of the maximum output power of the UE power class and the maximum allowed UL TX power indicated in this IE. The maximum UE TX power shall not be exceeded.

#### **7) Supporting ETSI Documents**

The attached documents included as Attachments A and B to the Technical Annex, presented and agreed during the ETSI GSM onboard aircraft studies, support the modeling methodology and assumptions used for Report 93 and 187, including with respect to aircraft attenuation and radiation from a leaky feeder.

## Attachment A

OnAir	GSMOBA-07077
European Telecommunications Standards Institute GSM OnBoard Aircraft Meeting #10 Oslo, Norway, October 8 – 9, 2008	

Source:	OnAir
Date:	September 30, 2008
Title:	Assessment of the phase correlation properties
Document for:	Information and discussion
Agenda	tbd

### Assessment of the phase correlation properties of a commercial passenger aircraft's RF emissions leaking through its windows

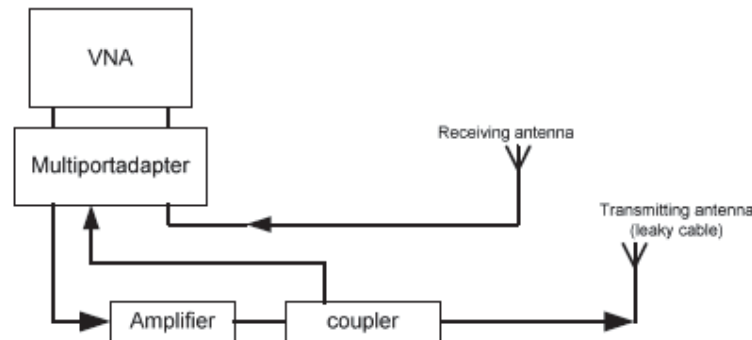
This contribution provides the result of a measurement campaign done in June/ July 2007 related to the assessment of the phase correlation whose aim was to answer whether an aircraft using a leaky cable antenna as radiating element, installed inside and along the aircraft cabin, has the potential to act as a phased-array when observed from a far-distant point (phased-array effect).

This contribution provides a description of the test methodology allowing measuring the phase and the magnitude of the RF signal received at each aircraft window. From the phase measurement, it can be observed whether there are some phase correlations between aircraft windows. By using the phase and magnitude results for each window and by using a superposition model, it was possible to extrapolate the radiation pattern at a given distance and to see whether there is a concentration of energy in a particular direction.

## 1 Test description

The measurement methodology was developed by the Institute for Electromagnetic Compatibility at the Technical University of Braunschweig, Germany. The phase and amplitude measurement was done for all frequencies relevant for GSM/BA operation. Four test frequencies corresponding to the operating NCU frequency bands were provided by BnetzA, the German regulatory Administration.

Figure 1 depicts the measurement test set up.



**Figure 1: measurement test set up**

The measurement was done by means of a Vector Network Analyzer (VNA) also known as scattering analyzer. In order to compensate the attenuation of the cables and the leaky cable antenna to achieve a sufficient dynamic range, the transmitted signals were amplified with an external amplifier during the measurement.

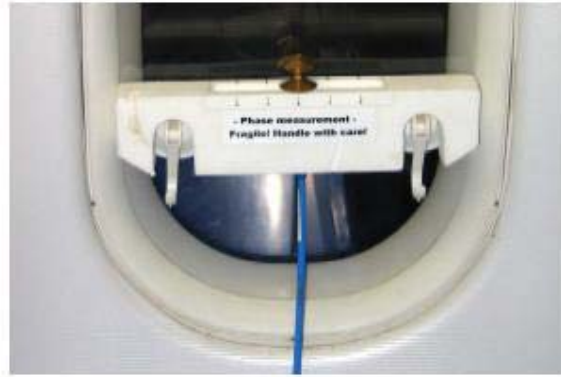
The reason for using the coupler and the multiport-adapter is justified by the fact that the calibration plane could not be defined at the leaky cable antenna and the receiving antenna inputs as the signal level provided at the amplifier output would have been too high for calibration and might have damaged the measurement equipment.

The multiport-adapter allows measuring either the signal injected into the leaky cable or the signal measured at the receiver antenna placed at the aircraft windows as depicted in Figure 2. In doing so, it was possible to determine the phase difference between the signal injected into the leaky cable and the signal received.

The tests required a receive antenna with a wide frequency range (between 400 MHz and 2.1 GHz) and a small size compared to the window (see Figure 2), in order not to change the electromagnetic field unduly.

The VNA is controlled through a laptop, which allowed to automatically carry out the measurements.

An initial measurement was carried out where the receive antenna was placed at different locations in the same aircraft window. The result of the measurement concluded that the phase measured was effectively the same for different locations in the window and hence can be represented by a single complex value.



**Figure 2: antenna installed at aircraft window**

Note that the aircraft window width is 23.6 cm.

## 2 Analysis and measurement result

As all devices used in the measurement were characterized through the Vector Network Analyzer, it was possible to determine what the magnitude and phase of the signal was at each aircraft window.

Figure 3 depicts the description of the different transfer functions of each element.

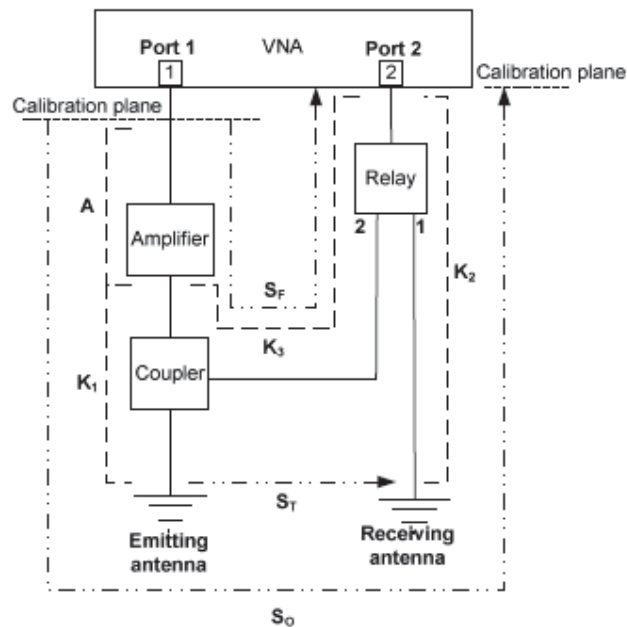


Figure 3: description of transfer function

$A(f)$ : the transfer function of the amplifier

$K_1(f)$ : transfer function of coupler (on the leaky cable side)

$K_2(f)$ : transfer function of cable + relay (multiport adapter)

$K_3(f)$ : transfer function of coupler + relay

$S_f(f)$ : transfer function of the amplifier, coupler and relay

$S_0(f)$ : transfer function of the whole loop (amplifier, coupler, leaky cable, receiving antenna and relay)

To determine the magnitude and phase of the signal at the window, the following equation applies:

$$S_T(f) = \frac{S_0(f)}{S_F(f)}$$

And

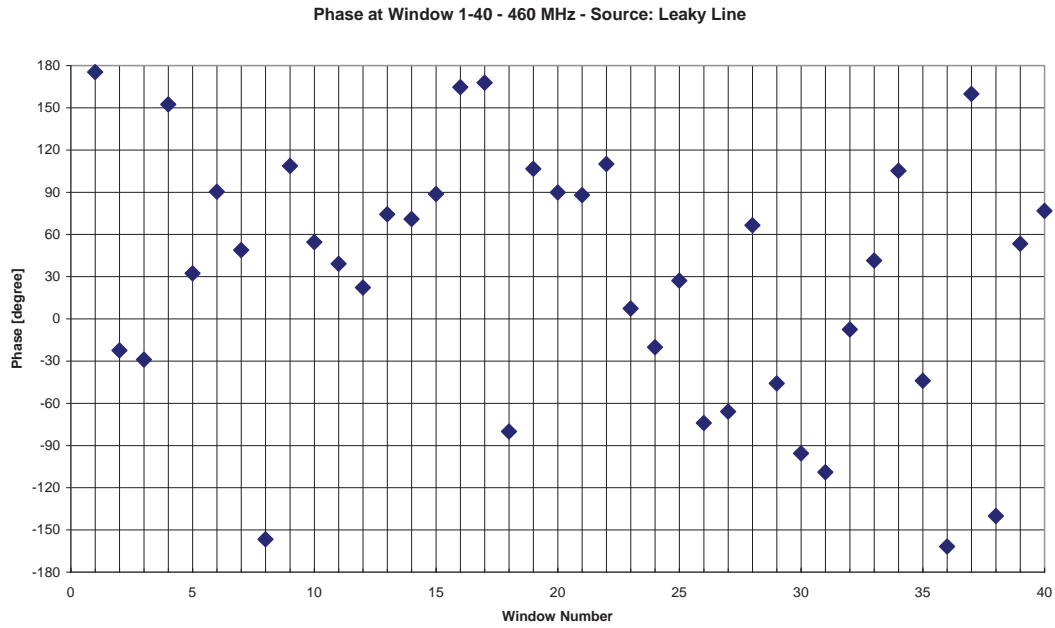
$$S_0(f) = A(f) \cdot K_1(f) \cdot S_T(f) \cdot K_2(f)$$

$$S_F(f) = A(f) \cdot K_3(f)$$

Gives us the following equation:

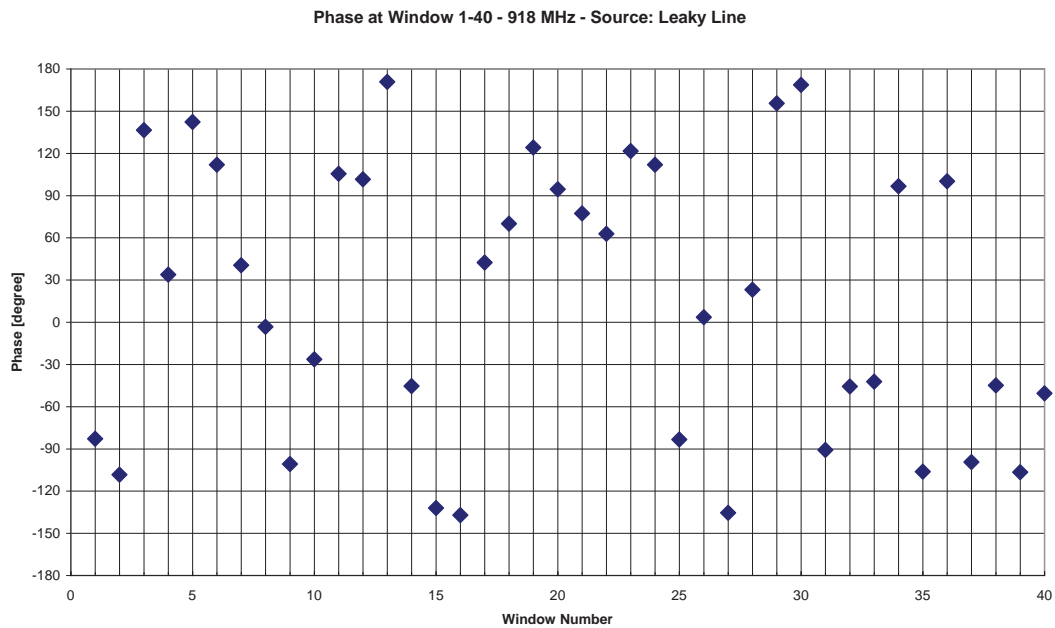
$$S_T(f) = \frac{S_0(f) \cdot K_3}{K_1(f) \cdot K_2(f) \cdot S_F(f)} = ae^{-j\phi}$$

Based on the above equation, it is possible to extract the phase and the magnitude of the signal at each window and for the frequency of interest. See Figure 4 to Figure 7 for the results obtained.



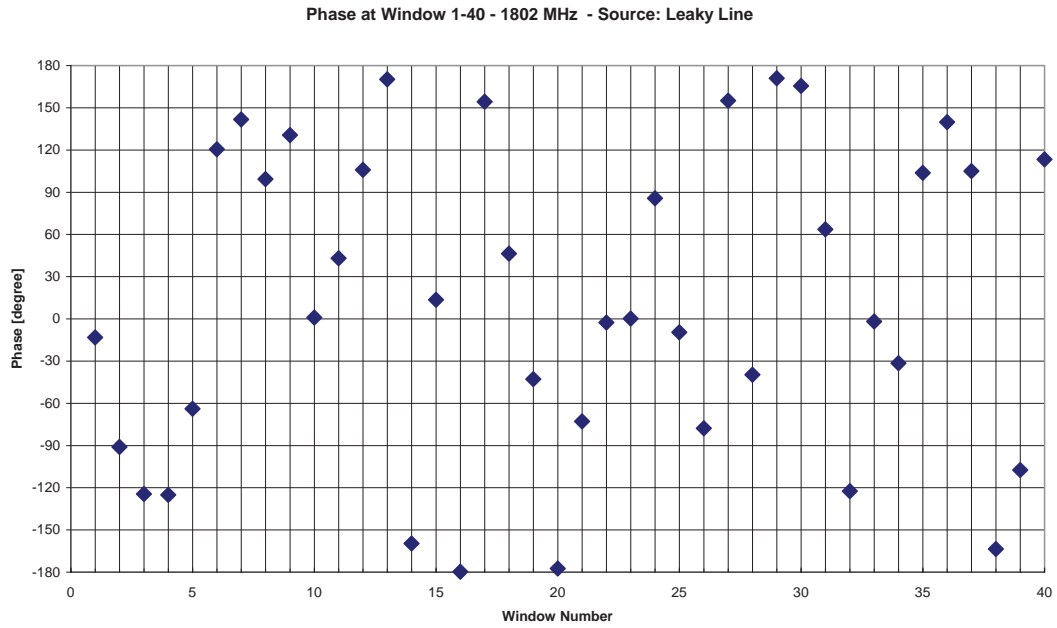
**Figure 4: Phase at windows at 460 MHz**

Figure 4 clearly shows that a correlated phase does not occur across all the aircraft windows nevertheless although some phase correlations (“dots closely aligned”) can be seen for the 450 MHz band in clumps of up to 3 aircraft windows.



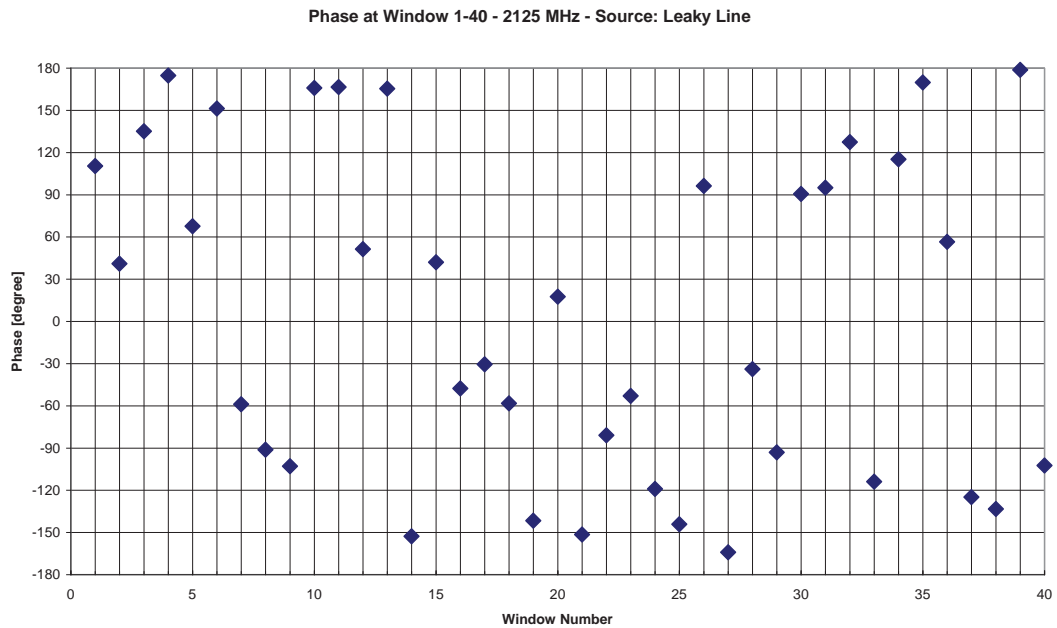
**Figure 5: Phase at windows at 918 MHz**

Figure 5 clearly shows that a correlated phase does not occur across all the aircraft windows phase correlation. However for the 900 MHz band some correlation of about three aircraft windows (window 20 - 22) is observed.



**Figure 6: Phase at windows at 1802 MHz**

Figure 6 shows that a correlated phase does not occur across all the aircraft windows with some correlation of up to about three aircraft windows is observed for the 1800 MHz band.



**Figure 7: Phase at window at 2125 MHz**

Figure 7 shows that a correlated phase does not occur across all the aircraft windows but for the 2GHz band at particular windows, a phase correlation of up to three aircraft windows can be observed.

In summary Figure 4 - Figure 7 clearly show that a correlated phase does not occur across all the aircraft windows for any of the four frequencies used. Nevertheless some phase correlation of up to three aircraft windows is observed.

### 3 Post-analysis

The results of the tests have shown that while some correlation occurs across up to three neighbouring windows there is no phase correlation observed across the full length of the fuselage. In order to see the relative impact of this distribution on the radiation pattern some distance away then the cumulative effect of multiple windows has to be calculated using the superposition model.

The results of this analysis can then be compared with a theoretical approach which assumes that all transmitting points are in phase and the amplitude is the same for each point. The likelihood of a phased array can then be deduced.

#### 3.1 Description of the superposition model

For assessing these measurement results, a mathematical model known as the superposition model is used which assumes that each aircraft window acts as an isotropic radiator and is fed by a source inside the aircraft. Each source point is characterized by its magnitude  $a_n$ , its phase  $\varphi_n$  and its wavelength  $\lambda$ . As it is assumed that there are no obstacles, the free-space path loss for each distance  $l_{n,\alpha}$  is used in this superposition model. For a given angle  $\alpha$ , the field is calculated at the distance  $D$  by aggregating the fields excited by the corresponding aircraft windows. Each window mid point is separated by 53.34 cm distance from each other.

The superposition model equation is as follow:

$$R_\alpha = \frac{1}{R_{\max}} \left| \sum_{n=1}^N a_n e^{-j(\frac{2\pi}{\lambda} l_{n,\alpha} + \varphi_n)} \left( \frac{\lambda}{4\pi \cdot l_{n,\alpha}} \right)^2 \right|$$

$$R_{\max} = \max \left\{ \left| \sum_{n=1}^N a_n e^{-j(\frac{2\pi}{\lambda} l_{n,\alpha} + \varphi_n)} \left( \frac{\lambda}{4\pi \cdot l_{n,\alpha}} \right)^2 \right| \right\}$$

$$l_{n,\alpha} = \sqrt{(D - d_n \cdot \sin \alpha)^2 + (d_n \cdot \cos \alpha)^2}$$

Where

$D$ :	the distance from the aircraft to a given point;
$a$ :	the signal amplitude at the aircraft window;
$N$ :	the number of aircraft windows
$d_n$ :	the separation distance between the window and the center of the array
$R_{\max}$ :	the maximum field-strength found considering all angles $\alpha$
$R_\alpha$ :	the normalized value for a given angle $\alpha$ and

$$\left( \frac{\lambda}{4 \cdot \pi \cdot l_{n,\alpha}} \right)^2 : \quad \text{being the free-space loss}$$

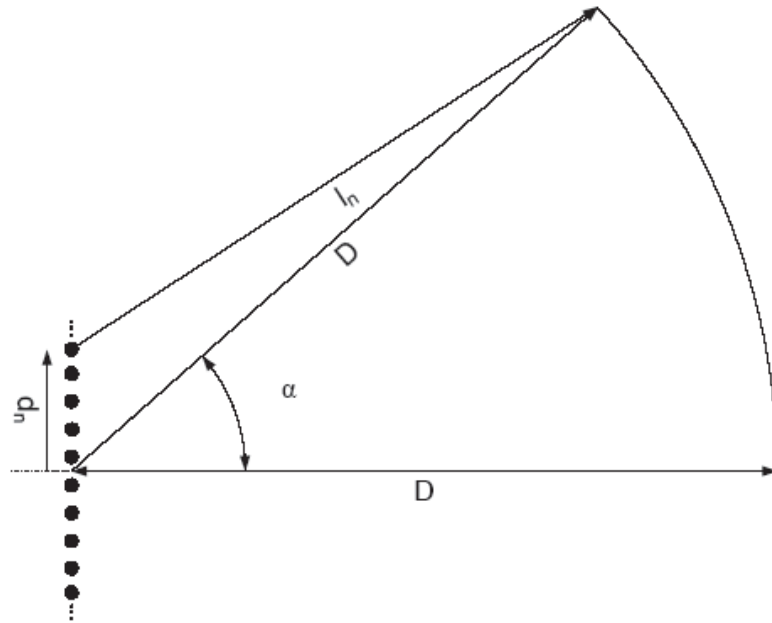


Figure 8: Geometrical representation of the superposition model

Figure 9 shows an example application of this superposition model for 1802 MHz. For the calculation, it is assumed that all windows are phase- and amplitude-coherently excited. The calculation was done for the angle  $\alpha$  ranging from  $-90^\circ$  to  $90^\circ$  and a distance  $D$  of 10km.

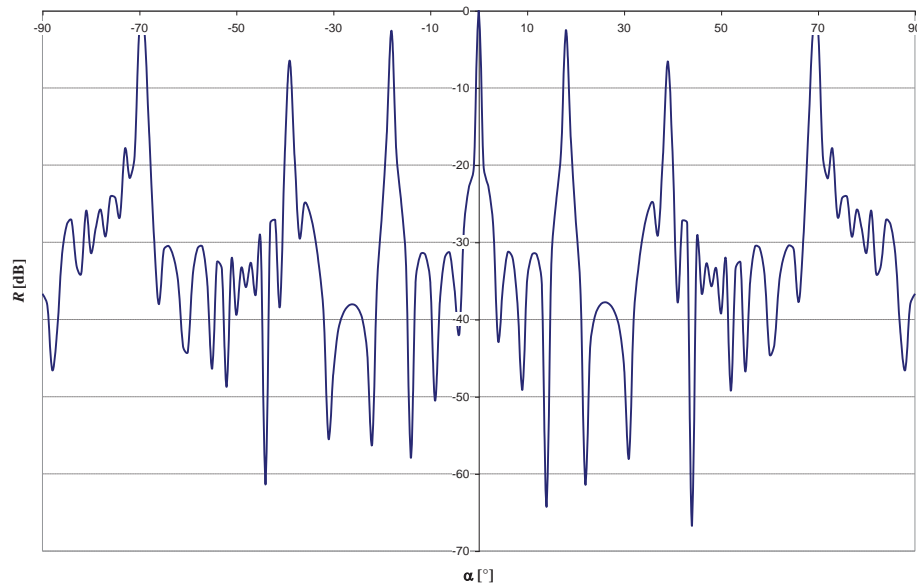
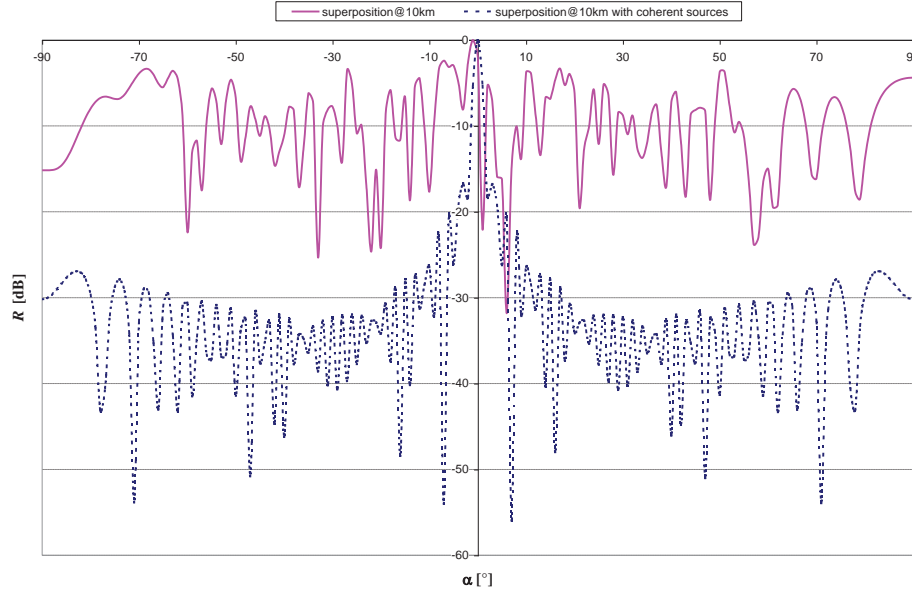


Figure 9: Calculated normalized radiation pattern at 1802 MHz and 10 km distance assuming phase- and amplitude-coherent excitation of the radiating elements

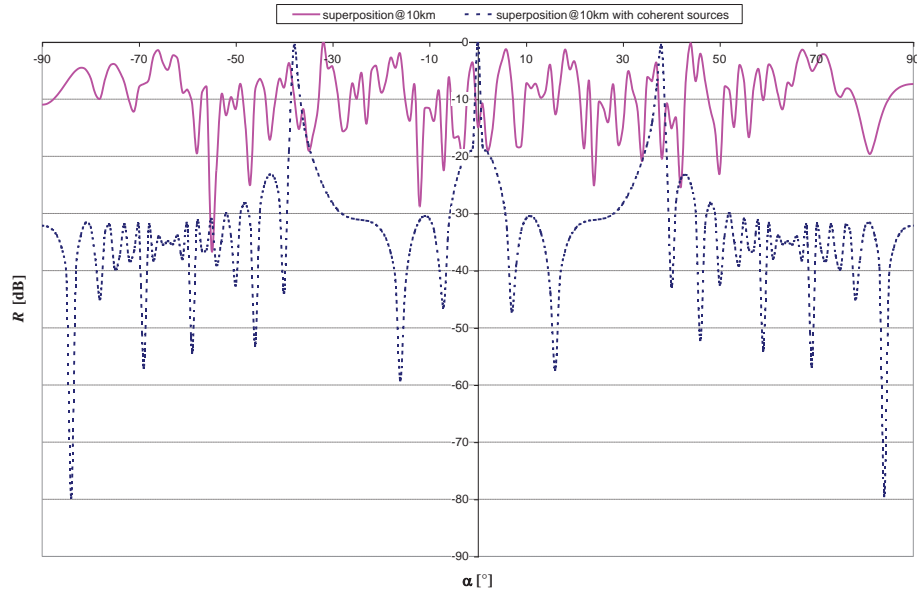
### 3.2 Comparing real radiation pattern with coherent excitation model

Based on the phase and magnitude measurement results, it is possible to extrapolate the normalized radiation pattern at a given distance  $D$  and angle  $\alpha$  by applying the measured phase and amplitude values to the superposition model. The following graphs show the results of the calculation using both the measured values (solid curve) and coherent sources for each window (dotted curve).



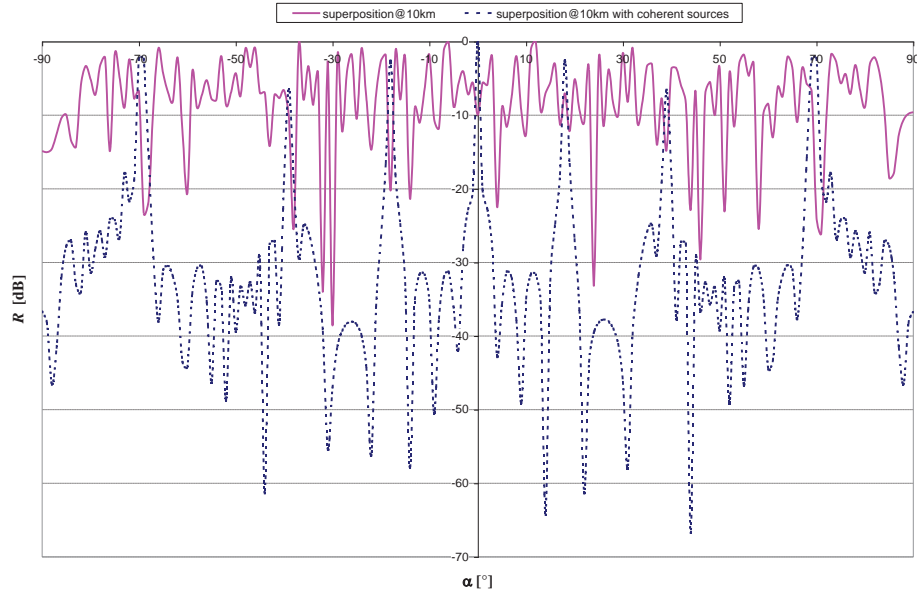
**Figure 10: Normalized radiation pattern at 460 MHz and at 10 km distance**

From Figure 10, it can be observed that the pattern obtained from the measurement at 460 MHz has a considerably different form as the theoretical pattern obtained from coherent signals. The coherent model clearly shows a strongly directive pattern with a single lobe, whereas the curve calculated from the measurement results show no concentration of energy at any particular angle in a 10 km distance. Hence, any gain effect of the aircraft caused by a phased-array effect can be excluded.



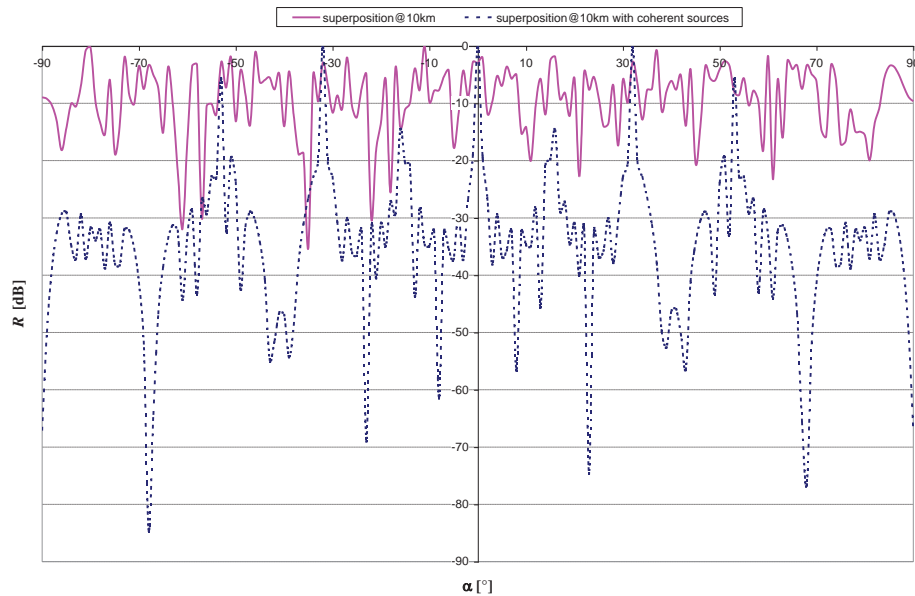
**Figure 11: Normalized radiation pattern at 918 MHz and at 10 km distance**

From Figure 11 it can be observed that the extrapolation of the coherent sources provides a directive profile, which is not reflected in the measurement results. The measurements show no concentration of energy at any particular angle 10 km distance away from the aircraft and hence, any gain effect of the aircraft caused by a phased-array effect can be excluded.



**Figure 12: Normalized radiation pattern at 1802 MHz and at 10 km distance**

The measured results at 1800 MHz (see Figure 12 ) show an even distribution of signal across angles and no phased array phenomena (i.e. no pronounced gain) effect is observed.



**Figure 13: Normalized radiation pattern at 2150 MHz and at 10 km distance**

Given the random distribution of signals for the measured results shown in Figure 13 no gain effect is observed at 10 km distance for at 2 GHz.

The main conclusion from the calculation results shown in Figure 10 - Figure 13 is that the radiation patterns using the extrapolated measured values do not have the same form than using coherent sources at each window. Further the radiation patterns produced do not show any combined signal which may give an array effect at a given distance (i.e. no marked gain shown). Even at the longest distance calculated (i.e. 10 km) there is no concentration of energy at a specific angle.

#### 4 Conclusion

A measurement campaign took place in June 2007 in order to assess the phase and magnitude of the signal reaching each aircraft window when illuminated by a leaky cable antenna according to the commercial Mobile OnAir solution.

The phase measurements at each window show that phase correlation across all the aircraft windows could not be observed. However, some phase correlation of up to 3 aircraft windows can be seen.

Based on the superposition model, a radiation pattern was calculated for an observation distance of 10 kilometres by assuming that the signal at all windows was phase-coherently excited and gets the same amplitude. This reference radiation pattern was then compared with the same extrapolation method but using the measurement results obtained (phase and magnitude). The measured results using the superposition model does not show a concentrated peak of energy and no specific beam form is observed. From these calculations, it is shown that under practical conditions a phased-array effect cannot be observed for a distance of 10 km.

Moreover, the measurement results of the ground and the in-flight measurement campaign confirm this conclusion (see contribution GSMOBA-07078). It can be observed that the attenuation at window obtained for the seat 4A (which is closest to the window) is similar to the attenuation at window at seat 6D whose location is seen from several aircraft windows.

Finally observing that any type of phase correlation at most can only be seen up to three aircraft windows depending of the frequency then the equivalent antenna can be considered as having an effective length of much smaller than the entire length of the aircraft cabin. Indeed the ground measurement does not need to be conducted at around 3 km away from the aircraft as it was suggested in some early GSMOBA meeting.

## Attachment B

	<b>GSMOBA-07078</b>
<b>European Telecommunications Standards Institute</b> <b>GSM Onboard Aircraft</b> <b>Meeting # 10</b> <b>Oslo, Norway, October 8 – 9, 2008</b>	

<b>Source:</b>	OnAir
<b>Date:</b>	September 30, 2008
<b>Title:</b>	OnAir / Airbus Ground and flight measurement results
<b>Document for:</b>	Information
<b>Agenda</b>	tbd

## Ground and flight measurement results

### Background

In June/July 2007 a ground and in-flight measurement campaign was conducted on an Airbus A320 aircraft; ground measurements taking place at the Airbus premise located in Hamburg and in-flight measurements nearby in the area of the mountain “Brocken” in northern Germany. The aim was to compare the results obtained during the ground and in-flight measurement and to see whether the ground measurement was sufficient to define the key aircraft RF parameters to calculate the effective power transmitted by the aircraft. These parameters are:

- Effective aircraft attenuation at the window;
- Effective aircraft attenuation in combination with the leaky cable.

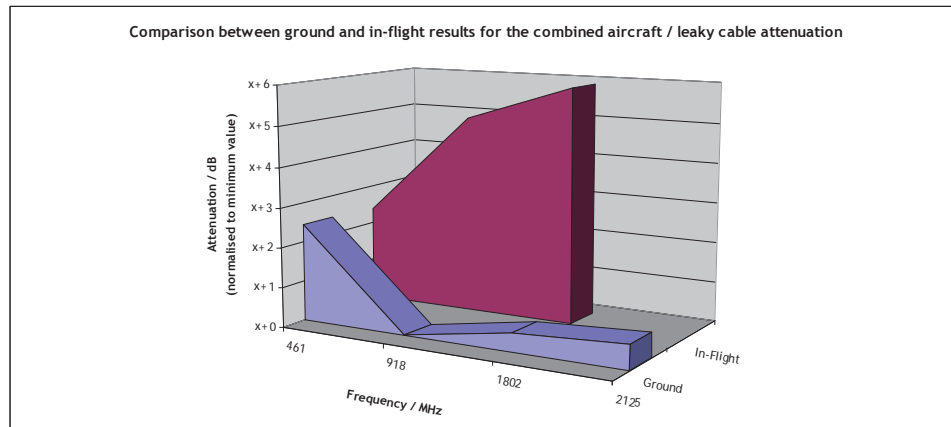
The measurements were carried out at the frequencies close to those operated by the NCU, i.e. 460 MHz, 900 MHz, 1800 MHz and 2100 MHz.

The OnAir/Airbus contribution GSMOBA-07066 was presented at the ETSI GSMOBA#9 meeting (December 2007), it describes the ground and in-flight measurement campaigns carried out.

This contribution provides the results and comparison of the ground and in-flight measurements.

### Results

Figure 1 shows the values obtained from both the ground and in-flight measurements for the “aircraft attenuation in combination with the leaky cable” the values presented are given as deltas to the minimum attenuation “x” that was calculated.



**Figure 14: Comparison between ground and in-flight results for aircraft attenuation in combination of the leaky cable**

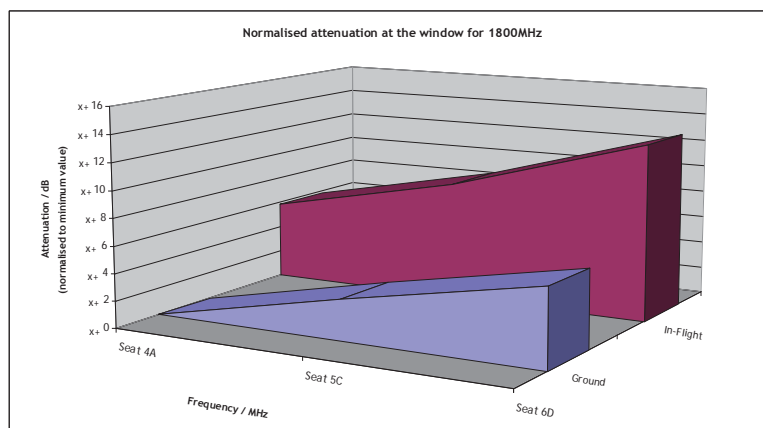
Table 1 shows the actual difference between the ground measurement results and the in-flight measurement results for the aircraft attenuation in combination with the leaky cable.

Frequency band (MHz)	461.075	918	1802
Difference (dB) between attenuation on the ground and attenuation in-flight	0.05	-4.99	-5.44

**Table 1: Difference between ground and in-flight aircraft attenuation in combination of the leaky cable**

**Note:** Due to emission power restrictions and pass-filter constraints it was not possible to overcome the large free-space path loss and antenna coupling loss at 2.1 GHz in order to measure enough data to derive reliable signal statistics.

Figure 2 shows the normalised aircraft attenuation values for the ground and in-flight measurements at the three seat positions 4A, 5C and 6D for the 1800 MHz band.



**Figure 15: Attenuation at the window for ground and in-flight measurements at 1800 MHz normalised to the minimum attenuation calculated**

Table 2 shows the difference between the ground and the in-flight measurement results for the aircraft attenuation at window:

Frequency band (MHz)	1802		
Seat	4A	5C	6D
Difference (dB) between attenuation on ground and attenuation in-flight	-5.85	-5.80	-7.24

Table 2: Difference between ground and in-flight attenuation at window

## Conclusion

On observing the results obtained it is clear that the values measured on the ground are much lower than the values obtained during the in-flight measurement.

Further on considering these results with the results obtained in the measurement of the phase across the length of the fuselage (see contributions GSMOBA-07077) we can conclude the following:

1. There is no coherent phase along the length of the fuselage.
2. Any phase coherency observed only exists across approximately 3 windows.

Consequently the effective size of the “antenna” can be considered no larger than 3 window spacing (for an Airbus A320 single aisle aircraft this equates to 1.30metres) leading to a boundary condition for the far-field at approximately 25 metres.

3. The ground tests were carried out at a distance of 50 metres from the aircraft, i.e. outside this boundary distance, and hence can be considered as the far-field region of the system.
4. The results of the flight tests show no sudden gain and hence no phase array is observed.
5. Comparisons of the ground and in-flight results show that ground tests measurements are more conservative than flight test values.
6. Given the lower costs and reduced administration and manpower needed to carry out ground tests compared to flight tests then OnAir proposes that ground test be chosen as an accepted method for determining the RF characteristics of the aircraft as long as the following criteria are met:
  - a. The measurement distance is located in the far-field region. Minimum separation between aircraft and antenna is hence defined by the effective antenna aperture determined by  $2 * \text{distance\_between\_window\_centres} + \text{window\_width}$  (= max. extent of three windows).
  - b. Ground tests are carried outside and away from building and other large obstacles.
  - c. Antennas are selected such, that the whole aircraft is within 3dB-antenna beamwidth.
  - d. The outside antenna height should be at least equal to the window height and the Fresnel Zone at half distance between the transmitter and the receiver should not be obstructed in order not to have additional absorption/ reflection on the ground (the worst case is for the lowest frequency, i.e. 460 MHz)